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(54) **IMAGING SYSTEM AND METHOD**

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(52) U.S. Cl. 358/1.9; 382/167; 358/506
(58) Field of Search 358/518; 382/162, 382/167; 758/1.9, 506, 487

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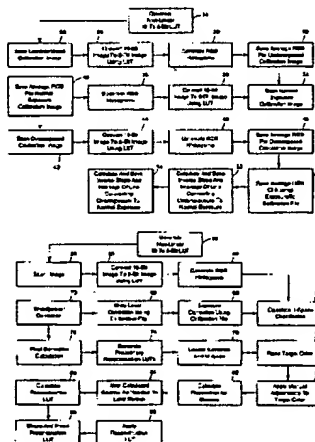5(2):93–104 (1979).

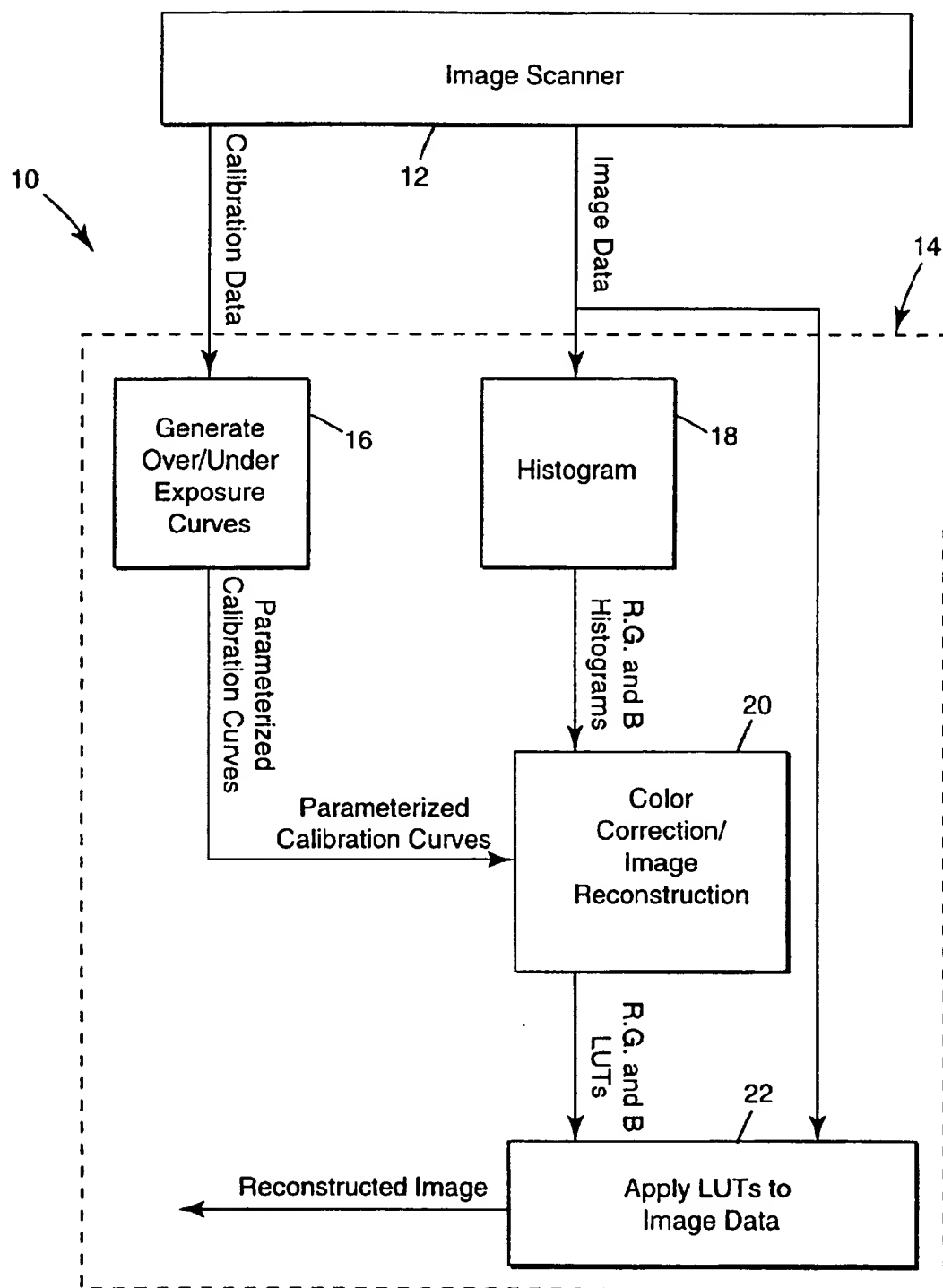* cited by examiner

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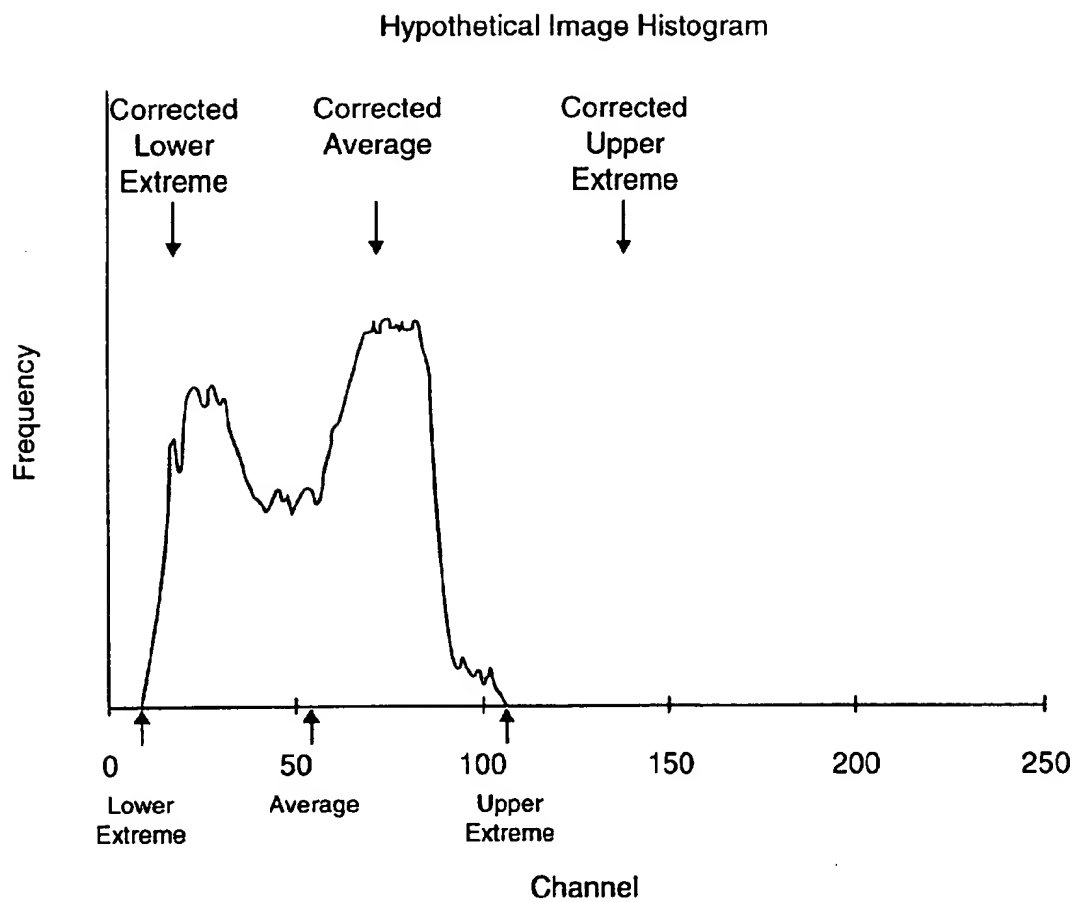(74) Attorney, Agent, or Firm—Shumaker & Sieffert, PA
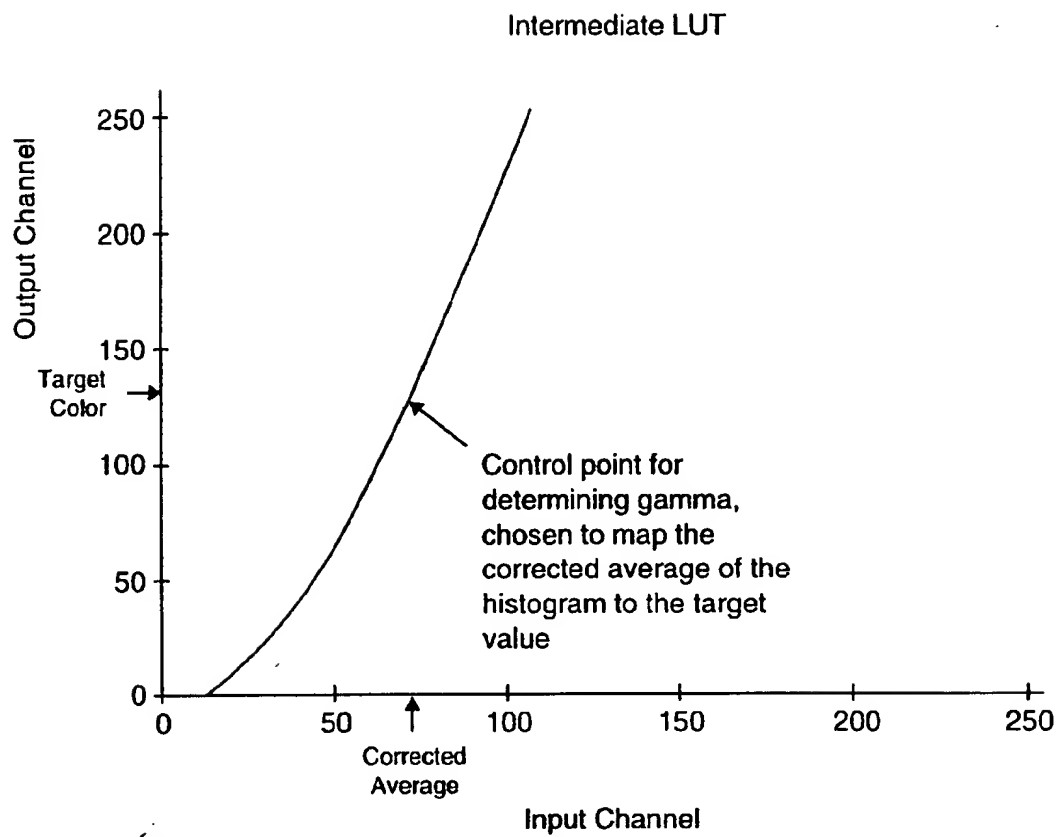
(57) **ABSTRACT**

A system and method for correction and reconstruction of
digital color images make use of one or more of a set of
algorithms for color calibration and correction, and recon-
struction. An algorithm for optimized bit depth reduction
also can be used to match the response curve of the scanner
to that of the scanned media, thereby improving signal-to-
noise ratio and decreasing artifacts such as pixelization,
which can result from sampling the tone curve too coarsely.
In a photographic film application, in particular, a color
calibration and correction algorithm enables correction of
the image for variations in hue from film type to film type,
over-exposure or under-exposure, exposure-induced hue
shifts, hue shifts caused by lighting effects, processing
related hue shifts, and other variables in film processing,
while preserving overall hue of the subject matter in the
originally photographed image. An image reconstruction
algorithm allows creation of look-up tables (LUTs) that
create a visually pleasing version of the image when applied
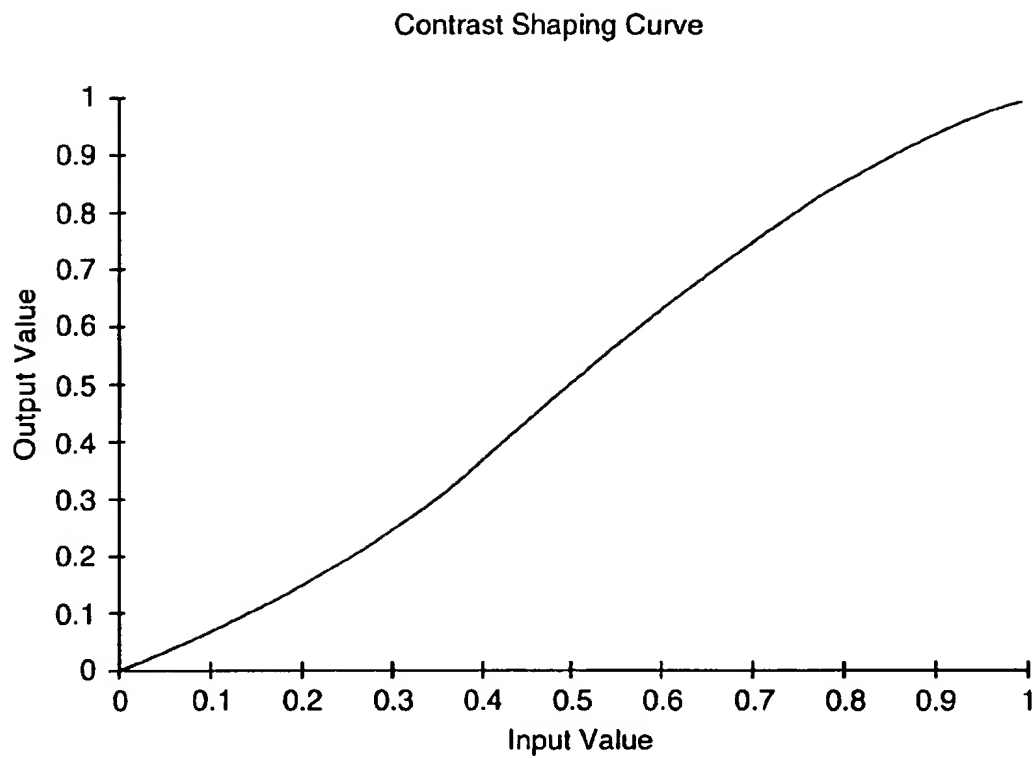to the original data.

34 Claims, 6 Drawing Sheets

Image Scanner

12

Calibration Data

Image Data

10

14

Generate Over/Under Exposure Curves — 16

Histogram — 18

Parameterized Calibration Curves

R.G. and B Histograms

Parameterized Calibration Curves

Color Correction/ Image Reconstruction

20

R.G. and B LUTs

22

Reconstructed Image

Apply LUTs to Image Data

Fig. 1

Hypothetical Image Histogram

Fig. 2

Intermediate LUT

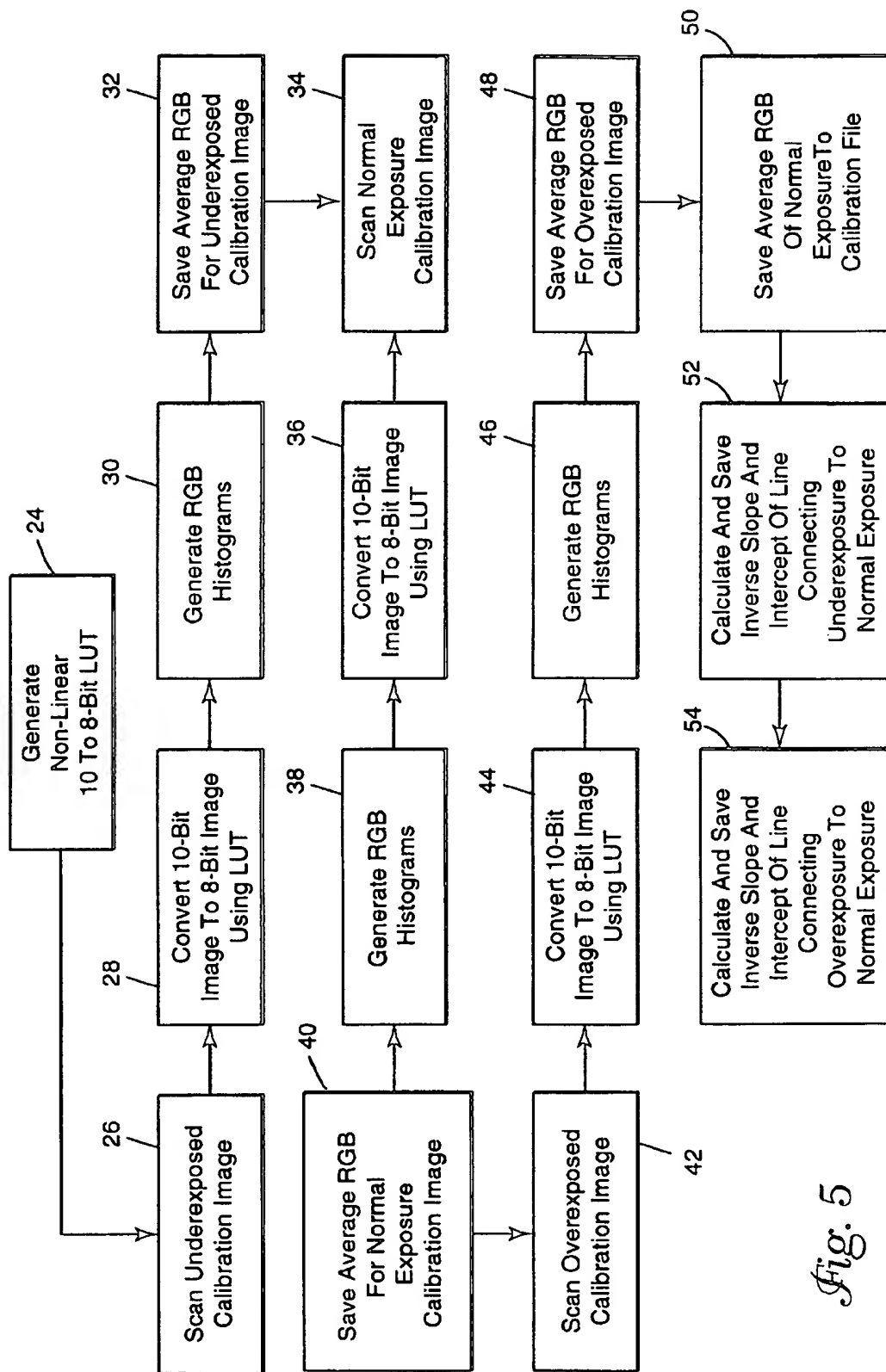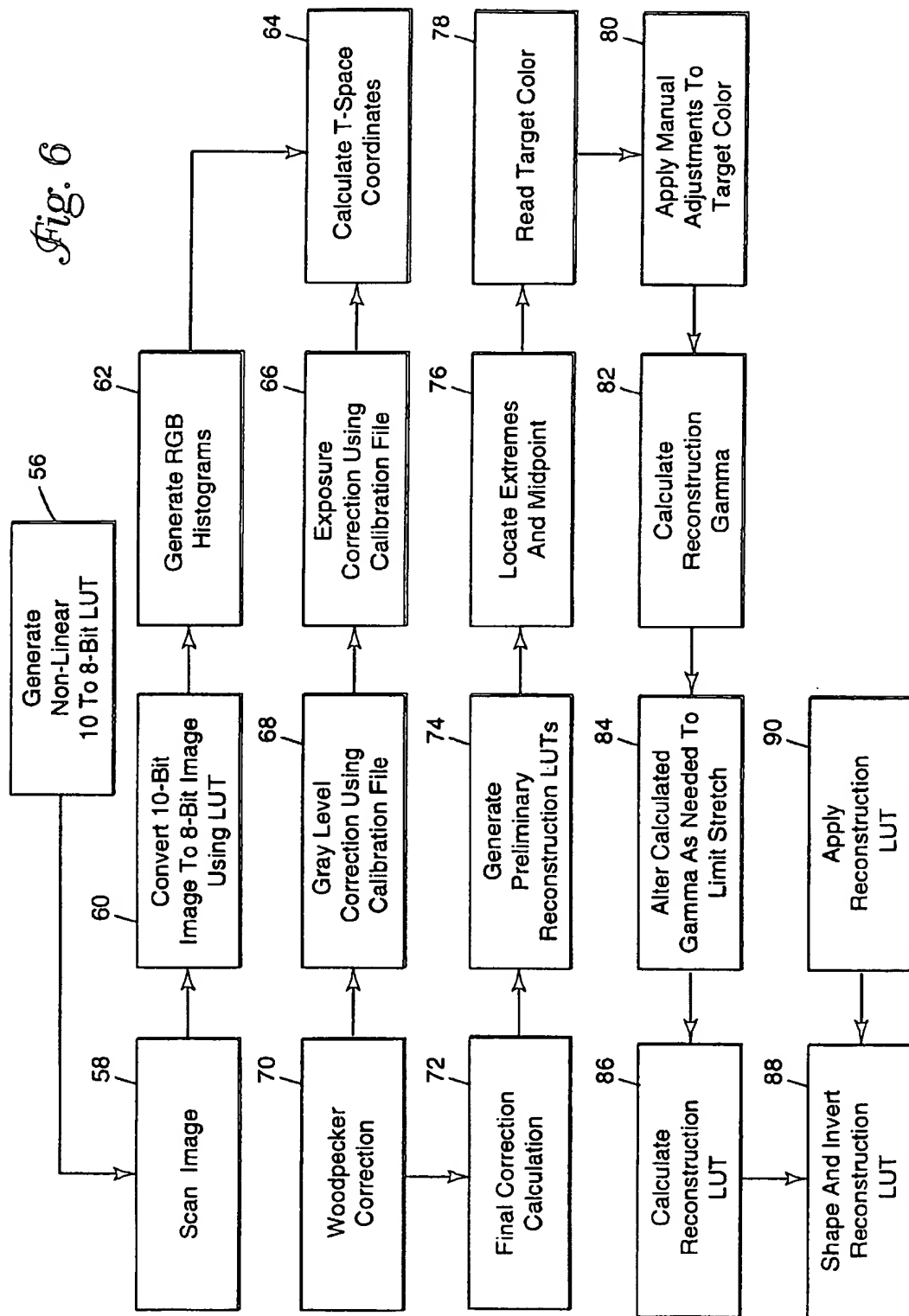*Fig. 3*

Contrast Shaping Curve

Fig. 4

Fig. 5

Fig. 6

IMAGING SYSTEM AND METHOD

This application claims priority from U.S. Provisional Application Ser. No. 60/092,867, filed Jul. 15, 1998, the entire content of which is incorporated herein by reference.

TECHNICAL FIELD

The present invention relates to techniques for scanning and reproducing images and, more particularly, to techniques for processing scanned image data to generate a digital image for display or reproduction.

BACKGROUND

Creation of positive images from photographic negatives can be a difficult and imprecise process. The fundamental problem is that the consumer wants to receive images that are consistently the correct color balance and brightness despite variables in the photographic imaging process. Sources of variation in the photographic imaging process include: (a) variations in spectrophotometric and sensitometric characteristics from film type to film type, (b) emulsion to emulsion variation within a film type, due to film manufacturing variability, film shelf aging before exposure, latent image fading after exposure, dark fading after processing, and chemistry variations in the film processing step, (c) illumination variation at the time of photography, which can cause both color balance variation in the image and exposure level variation, and (d) other variations, such as those arising from camera lens color differences. The challenge in photographic color correction is compensating for each of the above variables, while at the same time preserving color deviations from neutral in the image that are caused by the subject matter that was photographed.

SUMMARY

The present invention is directed to a system and method for correction and reconstruction of color images generated by a scanner. The system and method make use of one or more of a set of algorithms for color calibration and correction, and reconstruction of scanned images. The images can be scanned, for example, from reflective or transmissive film or paper. In particular, the images can be scanned from processed negative or positive photographic film. Other examples include photothermographic or thermographic film, electrographically printed paper, inkjet printed paper, and the like. For ease of illustration, all of the above media will be referred to herein as "film."

In a photographic film application, for example, a color calibration and correction algorithm enables correction of the image for variations in hue from film type to film type, over-exposure or under-exposure, exposure-induced hue shifts, hue shifts caused by lighting effects, processing related hue shifts, and other variations in film processing, while preserving overall hue of the subject matter in the originally photographed image. An image reconstruction algorithm allows creation of look-up tables (LUTs) that create a visually pleasing version of the image when applied to the original data. If desired, the system and method also may use an algorithm for optimized bit depth reduction that more effectively matches the response curve of the scanner to that of the film, thereby improving signal-to-noise ratio and decreasing artifacts such as pixelization, which can result from sampling the tone curve too coarsely.

In one embodiment, the present invention provides a method for correcting a digital color image scanned from

film, the method comprising producing average color value data for the scanned color image, performing exposure correction of the image using the average color value data and exposure calibration data, performing chromatic correction of the image using a subject failure suppression boundary following the exposure correction, generating image correction data representative of the exposure correction and the chromatic correction, and applying the image correction data to the image to produce a corrected color image.

In another embodiment, the present invention provides a system for correcting a digital color image scanned from film, the system comprising means for producing average color value data for the scanned color image, means for performing exposure correction of the image using the average color value data and exposure calibration data, means for performing chromatic correction of the image using a subject failure suppression boundary following the exposure correction, means for generating image correction data representative of the exposure correction and the chromatic correction, and means for applying the image correction data to the image to produce a corrected color image.

In a further embodiment, the present invention provides a method for reconstructing a digital color image scanned from film, the method comprising producing average RGB color value data for the scanned color image, performing exposure correction of the image using the average color value data and exposure calibration data, performing chromatic correction of the image using a subject failure suppression boundary following the exposure correction, generating image correction data representative of the exposure correction and the chromatic correction, generating reconstruction lookup tables (LUTs) based on the color correction data and the average color value data, each of the reconstruction LUTs representing a curve for reconstruction of one of the RGB color channels for the image, and applying each of the reconstruction LUTs independently for the respective RGB color channels to produce a reconstructed color image.

In an added embodiment, the present invention provides a system for reconstructing a digital color image scanned from film, the system comprising means for producing average RGB color value data for the scanned color image, means for performing exposure correction of the image using the average color value data and exposure calibration data, means for performing chromatic correction of the image using a subject failure suppression boundary following the exposure correction, means for generating image correction data representative of the exposure correction and the chromatic correction, means for generating reconstruction lookup tables (LUTs) based on the color correction data and the average color value data, each of the reconstruction lookup tables representing a curve for reconstruction of one of the RGB color channels for the image, and means for applying each of the reconstruction LUTs independently for the respective RGB color channels to produce a reconstructed color image.

In another embodiment, the present invention provides a method for correcting a digital color image scanned from film, the method comprising producing average color value data for the scanned color image, performing exposure correction of the image using the average color value data and exposure calibration data, performing chromatic correction of the image using a subject failure suppression boundary following the exposure correction, generating image correction data representative of the exposure correction and the chromatic correction, and applying the image correction data to the image to produce a corrected color image.

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In a further embodiment, the present invention provides a system for correcting a digital color image scanned from film, the system comprising means for producing average color value data for the scanned color image, means for performing exposure correction of the image using the average color value data and exposure calibration data, means for performing chromatic correction of the image using a subject failure suppression boundary following the exposure correction, means for generating image correction data representative of the exposure correction and the chromatic correction, and means for applying the image correction data to the image to produce a corrected color image.

Other advantages, features, and embodiments of the present invention will become apparent from the following detailed description and claims.

DESCRIPTION OF DRAWINGS

FIG. 1 is a functional block diagram of a system for correction and reconstruction of scanned color images;

FIG. 2 is a conceptual graph of a histogram generated for a hypothetical scanned film image;

FIG. 3 is a graph of a color correction and image reconstruction curve for a scanned image;

FIG. 4 is a graph of a contrast shaping curve for application to a curve as shown in FIG. 3;

FIG. 5 is a flow diagram illustrating a scan calibration method implemented by a system as shown in FIG. 1; and

FIG. 6 is a flow diagram illustrating a scan correction and reconstruction method implemented by a system as shown in FIG. 1.

Like reference numbers and designations in the various drawings indicate like elements.

DETAILED DESCRIPTION

FIG. 1 is a functional block diagram of a system 10 for correction and reconstruction of scanned color images. As shown in FIG. 1, system 10 may include an image scanner 12, and a software-based system 14 incorporating an exposure curve generation module 16, a histogram generation module 18, a color correction/image reconstruction module 20, and a LUT conversion module 22. For an exemplary photographic film scanning application, scanner 12 may take the form of a photographic film image scanner of the type typically used to scan negative film in roll format. Exposure curve generation module 16 processes calibration data generated by scanner 12 in response to calibration images, and produces calibration curves for correction of overexposed and underexposed images. The calibration curves can be stored for later use. Histogram generation module 18 processes image data generated by scanner 12 in response to actual user-provided images, and produces a histogram representing the distribution of the gray levels for the red, green, and blue (RGB) channels within the image. Color correction/image reconstruction module 20 processes the histogram generated by histogram generation module 18 and calibration curves generated by exposure curve generation module 16 to produce correction LUTs for each of the red, green, and blue color separations. Further, color correction/image reconstruction module 20 generates LUTs representative of a image reconstruction curve. LUT conversion module 22 applies the reconstruction LUTs to the actual image data generated by scanner 12 to produce a reconstructed image that can be used to generate high-quality reproductions of the original imagery.

Optimized Bit Depth Reduction

Scanner 12 may conform substantially to conventional image scanners useful in scanning film in a transmissive or

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reflective mode. In one embodiment, scanner 12 may incorporate scanning optics such as a line scanner oriented to apply a beam of light to processed, i.e., developed, photographic film, a light detector such as a CCD line scan array arranged to receive light transmitted through the film, and appropriate color filters for acquisition of color separation data from the CCD line scan array, e.g., red, green, and blue (RGB) color separation data. The light detector alternatively could include separate detector elements that are sensitized to respective color separations, eliminating the need for color channel filters. As an example, scanner 12 can be configured to scan each color separation at n-bit gray level accuracy, and then pass the resulting data through a n to m-bit conversion lookup table (LUT) in hardware integrated with the scanner, wherein m is less than n. In this manner, scanner 12 can perform bit depth reduction to more readily maintain a high scan throughput in terms of film frames scanned per minute.

The architectures of some scanners do not allow the entire n-bit dynamic range to be used to its full potential. For example, a scanner sometimes does not use the entire dynamic range available because some of the dynamic range is used to accommodate scanner-to-scanner variability caused by manufacturing variations and lamp brightness variations caused by aging. In some cases, as much as half of the dynamic range of the scanner can be dedicated to accommodating such variations.

Also, in some scanners, neither the exposure intensity nor the exposure time can be changed from image to image. As a result, over-exposures, normal exposures, and under-exposures must all be scanned within a common dynamic range. This limitation severely reduces the remaining dynamic range for any given image, because each image will have only one exposure level.

Finally, in a photographic film scanning application, photographic film does not have a linear relationship between transmittance, which is what the CCD detector measures, and exposure. Instead, this relationship is logarithmic. Consequently, gray level resolution which is adequate (or even more than needed) in the lighter areas of the film can provide inadequate resolution in the darker areas. Therefore, if scanner 12 undertakes a simple linear bit depth reduction from the n-bit input to the m-bit output, the light areas of the film are oversampled and the dark areas undersampled. This problem is most evident, on negative processed photographic film, in highlights of overexposures. In this case, the undersampling causes the measured levels to be severely quantized, leading to pixelization in the reconstructed image.

With the effects described above, after the n to m bit conversion, typical images produced by the scanner may have a substantially reduced dynamic range. Such a dynamic range is quite adequate for many applications, especially if the dynamic range is properly used. However, individual color separations of some images may have even fewer gray levels. In some cases, the number of gray levels may be too few to reconstruct an acceptable image. Images that represent scenes with low brightness ratio are by definition scenes with a lower number of gray levels. Accordingly, an algorithm for optimized bit depth reduction can be implemented within scanner 12 whereby the gray levels available in the 10 bit image are used more wisely to minimize artifacts. The algorithm can be implemented in hardware, firmware, software or a combination thereof within scanner 12. Alternatively, optimization of bit depth reduction could be assigned to a device external to scanner 12 that receives the n-bit, e.g., 10-bit, output from the scanner. As a further

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alternative, scanner **12** may produce n-bit data that is subjected to optimized bit depth reduction via a software module associated with system **10**. In particular, optimized bit depth reduction can be integrated with the color correction algorithm and carried out by color correction/image reconstruction module **20**. In this manner, optimized bit depth reduction may form part of the color correction.

The inherent transmittance of photographic film is logarithmic. Therefore, it makes sense for the detector measuring transmittance to measure logarithmically as well. The tone curve optimization algorithm takes this approach, and thereby reduces the complexity of the conversion. According to the tone curve optimization algorithm, the values of the darkest usable portion and the lightest exposed portion of the film are measured in the 10-bit space. The range is then scaled using a gamma correction curve, $y=ax^g+b$, instead of a logarithmic curve, mapping the range to a 2^m-level space. The 2^m-level space is mapped, however, subject to the constraint that the maximum step size is 1. This constraint forces the algorithm to use every available m-bit value, keeping the measurement as smooth as possible. The use of a gamma correction type curve instead of a logarithmic curve is preferred because the gamma curve is easier to handle from a computational standpoint. Also, from a practical standpoint, the two curves have a very similar shape, so that in actual use, the results are similar with either curve.

An advantage of this technique is that it better utilizes the inherent n-bit accuracy in that portion of the transmittance curve of the film where it is most needed, i.e., in lighter areas, while giving up some accuracy in portions of the transmittance curve that are being oversampled. In other words, accuracy is improved for the lighter portions of the processed photographic film and reduced in the darker portions. Thus, there is gain in accuracy where it is needed without appreciably sacrificing accuracy in any other portion of the film. Utilizing this technique significantly decreases the level—both frequency of occurrence and severity—of pixelization artifacts.

Color Calibration and Correction

In another embodiment, the present invention implements an algorithm for color correction of digitized imagery, such as that scanned from processed photographic film, or other film or paper media. Color correction can be implemented in software, in part by exposure curve generation module **16**, which generates calibration exposure curves for correction of variations due to under-exposure or over-exposure of a scanned image, histogram generation module **18**, which generates histogram information representative of density levels for a given color separation, and color correction/image reconstruction module **20**, which generates corrections based on the histogram information and the calibration exposure curves. This software implementation can be arranged in program code that is accessed and executed by a processor.

The program code can be loaded into memory from another memory device, such as a fixed hard drive or removable media device associated with system **10**. The processor may take the form of any conventional general purpose single- or multi-chip microprocessor such as a Pentium® processor, a Pentium Pro® processor, an 8051 processor, a MIPS processor, a Power PC® processor, or an Alpha® processor. In addition, the processor may be any conventional special purpose microprocessor. Further, the processor can be integrated within a personal computer or computer workstation that incorporates an input device,

such as a conventional keyboard and pointing device such as a mouse or trackball, and an output device, such as a CRT or flat panel computer monitor that provides textual and/or graphic output to the user.

The color correction algorithm can be applied, for example, to digitized output data generated according to a optimized bit depth reduction algorithm, as described above. Alternatively, the color correction algorithm can be applied to output data that has not been subject to bit depth reduction.

Algorithms for achieving accurate color correction have been developed for conventional photographic printing equipment. The so-called "integration to gray" theory, for example, is disclosed in U.S. Pat. No. 2,571,697 to Evans. A color correction algorithm based on the "integration to gray" theory can be implemented using a transformation from red-green-blue color space to a hue, saturation, and lightness (HSL) space. A color correction algorithm in accordance with this embodiment may use the "integration to gray" approach. This algorithm is designed to work in any of a number of HSL color spaces.

HSL color spaces can be expressed as either cylindrical coordinate systems or Cartesian coordinate systems, and generally have the following characteristics: (a) when the color space is expressed as cylindrical coordinate systems, variations along the theta axis are perceived by humans as shifts in the hue (e.g. red, yellow, green, cyan, blue, or magenta), variations along the radial axis are perceived as shifts in the saturation, e.g., low saturations are grayish, high saturations are intense or colorful, and variations along the z-axis are perceived as changes in the lightness of the object; and (b) when the color space is expressed as Cartesian coordinate systems, the x and y axes correspond to two opposite color pairs (frequently one is the red/green axis, and the other is the yellow/blue axis), and the z axis is again a lightness axis.

T space is one of several well known HSL color spaces. A T space is described, for example, in U.S. Pat. No. 4,159,174 to Rising and U.S. Pat. No. 4,154,523 to Rising et al. For implementation of the color correction algorithm in a photographic film application, T space may be desirable due to both its familiarity among film scanner users, and its ready correlation with the physical output of the film. Specifically, the x and y axes of T space are the GM (green/magenta) and ST (skylight/tungsten) axes. White objects illuminated by mixtures of outdoor lighting and indoor (incandescent) lighting appear at differing places along the S-T axis depending on the percentage of light from each source. This fact is useful in understanding the color correction algorithm described herein. Application of the algorithm in T space will be described for purposes of example. However, other possible HSL spaces would work just as well. Also, the conversion to the chosen space can be isolated to one small section of the computer code used to implement the algorithm, thereby facilitating ready change if use of another space is desired. A conversion to another color space could require, however, recalibration of the system and reselection of the subject failure suppression boundaries (SFSB or "woodpecker boundaries") and reconstruction targets, as will be described.

After the images have been scanned and output data has been produced, e.g., using an algorithm for optimized bit depth reduction within scanner **12** as described above, the color correction algorithm is applied to correct exposure level and remove unwanted color casts. The color correction algorithm is scanner independent. The first step of the

algorithm is to generate a histogram of the number of pixels at each brightness level for each color separation. The histogram information is used, in part, to yield average color value data indicating the average color values within the image. Other conventional methods for producing average color value data can be used. With reference to FIG. 1, the generation of average color value data can be assigned to discrete histogram generation software module **18** within software system **14**. The resulting histogram information for each color separation is passed into the color correction routine implemented within color correction/image reconstruction module **20**, as shown in FIG. 1. It is notable that the histogram information is the only information about the color content of the scanned image that the color correction/image reconstruction module **20** need receive. This feature is advantageous for commercial settings in which scanner **12** is used to scan images from film having diverse origins and characteristics, such as film received from amateur photographers in a photo processing shop.

Module **20** calculates the average RGB level in the image by reference to the histogram information, takes the log of such levels to account for the gamma of the film, and converts the values to T space. T space is related to RGB space by a simple matrix multiplication. By examining the location (relative to a normal exposure of a standard gray scene) of the average coordinates of the scene in T space, the exposure level of the scene can be estimated. Also, any systematic color shifts caused by lighting or other external influences can be determined from the S-T and G-M coordinates of the scene. Because the comparison is made to a standard of the same film type, film type-to-film type variations can be eliminated by calibration. For further information concerning film type calibration, reference is made to E. Goll, D. Hill, and W. Severin, Journal of Applied Photographic Engineering, Vol. 5, Num. 2, Spring 1979, pp. 93–104.

In order to carry out the color correction, standard reference films are obtained for each film type that is scanned. Because over- and under-exposures undergo hue shifts as well as changes in lightness, it is necessary to calibrate against such shifts. Thus, the calibration film should consist of a normal exposure, an underexposure, and an overexposure of a reference scene that is, on average, neutral gray. An example of suitable calibration films are the True Balance calibration strips made by Aperion Company for calibrating conventional analog photoprinters. Other calibration films that satisfy the above criteria would suffice. For calibration, each image is scanned, averaged, the logs are taken, and converted to T space, just as for the images to be corrected. This data is stored for each film type under a file name for its unique film type identifier code, i.e., a DX code. DX codes for photographic film are discussed in detail in American National Standards Institute standard ANSI/NAPM IT1.14-1994. In this manner, calibration data is assembled for a variety of film manufacturers, film types, and film speeds. Many conventional film scanners include a bar code reader configured to read the DX code from a roll of film and pass it to processing software along with the scanned image data.

After image coordinates in T space have been calculated, the corrections required to move the image back to normal exposure and remove color casts are calculated in four steps: (1) exposure correction, (2) gray correction, (3) chromatic correction using the subject failure suppression (or "woodpecker,") boundary, and (4) final correction.

For exposure correction, step (1), image over- or under-exposure is corrected by comparing the lightness value of

the image to the lightness value of the standards for that DX code. The lightness correction is set equal to the difference between the image and the normal exposure standard. Color corrections along each of the color axes are calculated as a fraction of the color errors of the over- or under-exposure standard, depending on whether the image was determined to be over- or underexposed. The fraction chosen is the ratio of the distance between the image and the normal standard to the distance between the over- or under-exposed standard. This amounts to assuming that the exposure induced hue shift is linear with exposure. Although this is not exactly true, actual shifts are close enough to linear that, in practice, this assumption is quite usable. In other embodiments, the hue shift versus exposure curve could be modeled using spline, polynomial, or other curve-fitting functions.

These corrections are stored by the algorithm and applied to the image T space coordinates. After this step, there is a set of T space coordinates having a lightness of 0.0, meaning the image has the same exposure as a properly exposed neutral scene. The T space coordinates also have S-T and G-M values that are typically non-zero, and represent a mixture of lighting induced hue shifts, other objectionable hue shifts, and variations of the actual color of the scene from true neutral. At this stage, the algorithm has produce exposure-corrected T space coordinates of the image, notably prior to chromatic correction.

The exposure correction will introduce a desirable color shift in the corrected image if the over- or under-exposed image is not neutral relative to the normal exposure. This situation is common and is known as exposure dependent color shift. If the chromatic correction (using the subject suppression failure, or "woodpecker," boundary) were based on the exposure-uncorrected coordinates, the gray point would not be truly gray. Instead, the gray point would be away from gray by however far the exposure correction changed the S-T and G-M values. The color correction algorithm avoids this result by performing the chromatic correction after the exposure correction.

For gray correction, step (2), further color corrections are generated, but not yet applied, by calculating the difference between the normal exposure standard and the S-T and G-M values of the exposure-corrected scene. If applied, these corrections would make the average hue of the corrected image neutral gray. However, not all scenes are, on average, neutral gray. Accordingly, the gray correction data is held in abeyance for performance of the chromatic correction.

For chromatic correction using the subject failure suppression boundary, step (3), a comparison is made between the size of the preliminary color corrections previously determined from step (2) and a boundary in T space known as the subject failure suppression boundary, and colloquially known by those skilled in the art as the "woodpecker" boundary because of its resemblance to a profile view of the head of a woodpecker. This boundary is predetermined by examining the T space coordinates of many images, on an empirical basis, and hand picking a boundary which will provide appropriate correction. A line is projected from the origin of T space, through the coordinates of the preliminary color corrections of step (2), and to the point where the line intersects with the boundary.

A fraction is generated by dividing the distance of the correction from the origin of T space by the distance of the boundary from the origin at the point of intersection. If the fraction is below some lower limit (frequently 0.2), it is adjusted up to that lower limit. Then, the preliminary color corrections from step (2) are multiplied by the fraction to

generate a new set of corrections. The purpose of this step is to remove the effects of lighting-induced hue shifts while not removing scene content-induced hue shift. When the exact position of the boundary is chosen, it is carefully selected with this goal in mind. Implementation of the color correction algorithm as described herein allows the number of points used to define the boundary to be varied easily depending on the characteristics of the film, application, and the expected subject. Also, the algorithm allows the easy use of a different boundary for each film type.

For the final calculation of corrections, step (4), the actual corrections to be applied to the scene are calculated by adding together the exposure corrections generated in step 1 and the gray level/chromatic corrections generated in step 3. These corrections are converted back to RGB space, where they represent relative shifts in the scaling of the RGB data. These shifts, and the original histograms representing the image, are passed onto the image reconstruction algorithm. The image reconstruction algorithm may conform substantially to that described below, or may be selected from other available algorithms. Accordingly, correction and calibration, in accordance with the present invention, can be practiced separately from image reconstruction, as described herein, and vice versa.

Image Reconstruction

An image reconstruction algorithm can be implemented in software by color correction/image reconstruction module 20. For image reconstruction, the only information available is the R, G, and B histogram information for the scanned image. Even after the color corrections have been applied, only one color—the average hue of the image—has been corrected. Moreover, it is not even known what calorimetric values that color had in the original scene of the scanned image. There is no known white or black point, because no relationships between the R, G, and B values of any given pixel are known. The relationships were lost when the histograms were made. Similarly, there is no information to facilitate location of key colors like flesh tones, foliage green, sky blue, or neutral gray. This lack of colorimetric information means that the image reconstruction algorithm must be largely ad hoc. It can only be based on a general knowledge of film behavior, knowledge of how the human visual system works, and assumptions about likely scene content. Therefore, the image reconstruction algorithm is highly heuristic, but has been observed to produce good image quality results despite the dearth of information concerning the original image.

According to this image reconstruction algorithm, each channel (R, G, and B) is treated independently, and each step below is applied separately to each channel. First, a preliminary reconstruction LUT is calculated. The preliminary reconstruction LUT represents a "first estimate" of the reconstruction LUT, and is calculated by applying the scale factors calculated in the color correction algorithm to the integers between 0 and 255. Second, the algorithm locates extremes and midpoints. In particular, the lower and upper points of the histogram which actually contain data are located, as is the (uncorrected) average point. The preliminary reconstructed points corresponding to these three positions are also located, as illustrated by FIG. 2.

Next, a target color is determined. Specifically, the target for the average color to which the image is to be mapped is loaded from a file. This target color is conceptually a neutral gray. However, it may be chosen somewhat away from gray to accommodate the color characteristics of the final

intended display device, if known. Because of compromises with other image appearance factors, a neutral gray in the final image may not actually be mapped to this color.

Following determination of the target color, manual adjustments may be made, as will be described in greater detail later in this description. Gamma then is determined by calculating the parameters required to map the midpoint to the target color, while mapping the lower and upper ends of the histogram to 0 and 255, respectively. Mathematically, a, b, and g are calculated for the following equation: $y = a\ x^g + b$. Stretch of the gamma correction curve can be limited, if desired, as will be described in greater detail later in this description. A nearly final ("intermediate") version of the LUT is calculated next, using the gamma correction equation. An example of the curve represented by the LUT is shown in FIG. 3.

The contrast of the final image can be adjusted by applying a contrast shaping curve, as shown in FIG. 4, as a separate look-up function, to the intermediate LUT. This step both suppresses overstretch and lends a more aesthetically pleasing appearance to the image. As shown in FIG. 4, the rounded sections at the ends of the shaping curve tend to suppress pixelization, which typically occurs in the brightest or darkest regions of the image, and the higher slope in the center increases midtone contrast. The purpose of the contrast shaping function is to modify the nearly final LUT to achieve aesthetically pleasing results in the reconstructed image. Many possible functions could be used for the contrast shaping function. Included below is a discussion of an exemplary contrast shaping function. The contrast shaping function, in this example, can be represented by the following equation:

$$y = (1-x)s_1 \tan h(m_1(x-0.5)) + xs_2 \tan h(m_2(x-0.5)) \tfrac{1}{2}$$

In the above equation, tanh represents the mathematical function known as a hyperbolic tangent. The function is used by scaling the nearly final output value of each channel to the range between 0 and 1 by dividing it by the value of the largest allowed output value. In an 8-bit system, for example, the largest allowed output value is 255. The scaled value is then inserted as x into the contrast shaping function. The resulting y value is scaled back to the range between 0 and the largest allowed output value by multiplying it by the largest allowed output value.

The constants s_1 and s_2 in the contrast shaping function are chosen to keep the output value between 0 and 1. Typically, constants s_1 and s_2 are chosen so that the lowest possible output value is 0 and the highest is 1. However, in some of the low contrast cases detected in the "limit stretch" step, they may be chosen so that the lowest possible output value is greater than 0 and/or the highest possible output value is less than 1. The constants m_1 and m_2 are chosen to control the slope of the curve, and therefore the contrast of the image, in the middle of the curve (corresponding to the midtones of the image) and the amount of curvature in the high and low values of the curve (corresponding to the highlights and shadows of the image). Increasing the curvature of the curve can cause it to have a lower slope, and hence lower contrast, in selected areas of the image. This can be useful for, among other things, minimizing the effects of pixelization artifacts. In the example curve shown in FIG. 4, $S_1 = s_2 = 1/(2\tan h(0.5))$ and $m_1 = m_2 = 1$. It is not necessary that S_1 equal S_2, or that M_1 equal M_2; they can be chosen separately. S_1 and M_1 primarily affect the shape of the curve for low x values, whereas S_2 and M_2 primarily affect the shape of the curve for high x values.

As a final step, if the film is negative film, the LUT is inverted so that it will create a positive image when applied to the image data. LUT conversion module 22 then applies the final correction LUT to the scanned image data to reconstruct the scanned image for reproduction. The reconstructed image can be stored as an image file for later use, or immediately printed as a positive image on a conventional film printing device.

The basic algorithm described above, without the manual adjustment and stretch limit steps, has been observed to provide good results in most instances, and especially with "well behaved" images, i.e. those containing more than 100 gray levels per separation and having histograms that are either approximately flat in the areas where there are data, or peaked toward the middle. However, it is sometimes desirable to manually adjust overall scene brightness, contrast, and/or color balance. For this reason, color correction/image reconstruction module 20 can be configured to allow input of such adjustments. Thus, in the manual adjustment step, brightness and color balance adjustments can be made by adjusting the color target for each separation up or down depending on the direction and amount of change requested. Changing brightness involves adjusting all the channels equally, whereas changing color balance is achieved by adjusting them individually. Changing image contrast can be achieved by increasing or decreasing the slope of the contrast shaping curve.

As mentioned above, pixelization and quantization artifacts sometimes show up in images with relatively few gray levels in each separation. Because the reconstruction algorithm uses a non-linear mapping between input and output (this is done to reflect the fact that film response to exposure is non-linear; and in fact has substantially the same shape as the gamma correction curve), some gray levels end up with larger gaps between them and their neighbors than they would have in a linear reconstruction, while some end up with smaller gaps. Unfortunately, this gap variation can increase the artifacts in the large gap areas of the tone curve. This problem can be referred to as overstretch, because it results from stretching the dynamic range of the image too far in the attempt to make it fill the dynamic range of the output device. Overstretch can be detected and corrected in at least two ways.

First, if the overall dynamic range of the input image is below a given threshold, the contrast shaping curve can be adjusted to lower the contrast of the reconstructed image. This operation causes the reconstruction of a dynamically flat scene such as, say, an overcast sky, to be reconstructed as a gray image with subtle color and brightness variations, which is what it actually looks like. This is in contrast to having wildly modulated brightness shifts, which the basic algorithm could try to introduce by stretching the histogram to fill the whole range from 0 to 255. Second, images with histograms that are highly skewed to one end or the other can be identified. An example is a picture of campers gathered around a campfire at night. The image is mostly black, but has some light pixels corresponding to the fire. Consequently, this image exhibits good dynamic range and would not be detected by the dynamic range test described above. When the reconstruction stretches the average brightness point, which was in the middle of the hump of nearly black pixels, to the middle of the dynamic range, all the pixels darker than the average are overstretched. This case can be detected by directly looking for cases where the slope of the reconstruction curve is too high, and adjusting the brightness appropriately to bring it down.

FIG. 5 is a flow diagram further illustrating the operation of a scan calibration method implemented as described

above. With reference to FIG. 5, a non-linear 10 to 8-bit LUT is first generated to permit optimization of the tone curve produced by scanner 12 following bit depth reduction, as indicated by block 24. Again, the non-linear LUT can be constructed as a gamma correction curve to better match the logarithmic response of the film. Also, a maximum step constraint can be imposed to ensure that the entire 255 value range is utilized. With the non-linear LUT pre-calculated, a calibration routine is undertaken.

Specifically, as indicated by block 26, an underexposed calibration image is scanned by scanner 12. The 10-bit scan of the underexposed image is then converted to an 8-bit image using the pre-calculated LUT, as indicated by block 28. Histogram generation module 18 next generates histogram information for each color separation, as indicated by block 30, and saves the average red, green, and blue values for the underexposed calibration image, as indicated by block 32. The saved average will be used in the image correction algorithm.

Next, a normal exposure image is scanned by scanner 12, as indicated by block 34. The 10-bit scan of the normal-exposure image is converted to an 8-bit image using the pre-calculated LUT, as indicated by block 36. Histogram generation module 18 next generates histogram information for each color separation of the normal-exposure image, as indicated by block 38. The average red, green, and blue (RGB) values are saved for the normal exposure calibration image, as indicated by block 40.

Next, an overexposed calibration image is scanned, as indicated by block 42, and converted to an 8-bit image, as indicated by block 44. Following generation of histograms, as indicated by block 46, the average red, green, and blue values are saved, as indicated by block 48.

The calibration information is then parameterized for use in the color correction algorithm. Specifically, the average red, green, and blue values for the normal exposure calibration image are stored to a calibration file, as indicated by block 50. Also, the inverse slopes and intercepts of the line connecting the overexposure curve to the normal exposure curve and the line connecting the underexposure curve to the normal exposure curve are calculated, as indicated by blocks 52 and 54, for use in the color correction algorithm.

FIG. 6 is a flow diagram illustrating a scan correction and reconstruction method implemented as described above. As shown in FIG. 6, the non-linear conversion LUT is generated, as indicated by block 56. An image is then scanned and converted according to the LUT, as indicated by blocks 58 and 60. The converted image is processed by histogram generation module 18 to produce histogram information for the red, green, and blue channels, as indicated by block 62. Color correction/image reconstruction module 20 then calculates T-space coordinates for the image, as indicated by block 64. Using the calibration file generated as described with reference to FIG. 5, the image is corrected for over-exposure or under-exposure, as indicated by block 66.

Next, gray level correction is carried out, followed by chromatic correction, as indicated by blocks 68, 70, which pertain to gray level and subject failure suppression boundary (SFSB) correction, respectively. Calculation of final color correction data is undertaken, as indicated by block 72, by reference to the exposure correction and the gray level/chromatic correction.

The final correction is then used to form preliminary image reconstruction LUTs, as indicated by block 74. Following location of the extremes and midpoint of the preliminary reconstruction curve, as indicated by block 76, a target color for the particular film is read from memory or

input by the user, as indicated by block **78**. Optionally, a user then applies manual adjustments to the target color, as indicated by block **80**, before a gamma curve for image reconstruction is calculated, as indicated by block **82**.

If necessary, stretch is limited to reduce artifacts, as indicated by block **84**. Then, an intermediate reconstruction LUT is calculated, as indicated by block **86**. Following shaping and inversion of the reconstruction LUT, as indicated by block **88**, the resulting LUT is applied to the image data to reconstruct the image, as indicated by block **90**.

The present invention has been described primarily in the context of scanning negative color film. The algorithms implemented in accordance with the present invention may find ready application, however, in other film scanning systems. For example, black and white negatives could be handled by adapting the image reconstruction algorithm to handle single channel images. This can be accomplished by making all the channels the same, calibrating as usual, and scanning as usual. Further, the algorithms can be adapted to handle scanned positive (slide) film with some modification. The foregoing detailed description has been provided for a better understanding of the invention and is for exemplary purposes only. Modifications may be apparent to those skilled in the art, however, without deviating from the spirit and scope of the appended claims.

What is claimed is:

1. A method for correcting a digital color image scanned from film, the method comprising:

producing average color value data for the scanned color image;

performing exposure correction of the image using the average color value data and exposure calibration data;

performing chromatic correction of the image using a subject failure suppression boundary following the exposure correction;

generating image correction data representative of the exposure correction and the chromatic correction; and

applying the image correction data to the image to produce a corrected color image.

2. The method of claim 1, further comprising:

producing the average color value data by:

producing histogram information representative of a distribution of RGB color values within the scanned color image, and

determining average RGB color values within the image based on the histogram information;

converting the average RGB color values to HSL coordinate values; and

performing the exposure correction of the image using the HSL coordinate values and the exposure calibration data.

3. The method of claim 2, further comprising selecting the exposure calibration data based on the HSL coordinate values and a type of the film from which the color image was scanned.

4. The method of claim 3, further comprising selecting the exposure calibration data by:

selecting a set of the exposure calibration data corresponding to the type of film from which the color image was scanned;

determining whether the image was over-exposed, under-exposed, or normally exposed by comparing the HSL coordinate values to reference values; and

selecting a subset of the exposure calibration data based on whether the image was over-exposed, under-exposed, or normally exposed.

5. The method of claim 4, further comprising performing the exposure correction by:

adjusting the HSL lightness values for the image relative to HSL lightness values specified by the exposure calibration data; and

adjusting HSL color values for the image relative to HSL color values specified by the exposure calibration data.

6. The method of claim 2, wherein the exposure calibration data includes multiple sets of exposure calibration data, each of the sets corresponding to a type of film from which the image was scanned and an exposure level of the image.

7. The method of claim 2, further comprising scanning the image such that each of the RGB color values has a color resolution of n bits, and reducing the color resolution of the RGB color values to m bits following the application of the image correction data to the image to produce the corrected color image.

8. A system for correcting a digital color image scanned from film, the system comprising:

means for producing average color value data for the scanned color image;

means for performing exposure correction of the image using the average color value data and exposure calibration data;

means for performing chromatic correction of the image using a subject failure suppression boundary following the exposure correction;

means for generating image correction data representative of the exposure correction and the chromatic correction; and

means for applying the image correction data to the image to produce a corrected color image.

9. The system of claim 8, wherein the means for producing the average color value data produces histogram information representative of a distribution of RGB color values within the scanned color image, and determines average RGB color values within the image based on the histogram information, the system further comprising means for converting the average RGB color values to HSL coordinate values, wherein the means for performing exposure correction of the image uses the HSL coordinate values and the exposure calibration data.

10. The system of claim 9, further comprising means for selecting the exposure calibration data based on the HSL coordinate values and a type of the film from which the color image was scanned.

11. The system of claim 10, wherein the means for selecting the exposure calibration data further includes:

means for selecting a set of the exposure calibration data corresponding to the type of film from which the color image was scanned;

means for determining whether the image was over-exposed, under-exposed, or normally exposed by comparing the HSL coordinate values to reference values; and

means for selecting a subset of the exposure calibration data based on whether the image was over-exposed, under-exposed, or normally exposed.

12. The system of claim 11, wherein the means for performing the exposure correction further includes:

means for adjusting the HSL lightness values for the image relative to HSL lightness values specified by the exposure calibration data; and

means for adjusting HSL color values for the image relative to HSL color values specified by the exposure calibration data.

13. The system of claim **9**, wherein the exposure calibration data includes multiple sets of exposure calibration data, each of the sets corresponding to a type of film from which the image was scanned and an exposure level of the image.

14. The system of claim **9**, further comprising means for scanning the image such that each of the RGB color values has a color resolution of n bits, and means for reducing the color resolution of the RGB color values to m bits following the application of the image correction data to the image to produce the corrected color image.

15. A method for reconstructing a digital color image scanned from film, the method comprising:

producing average RGB color value data for the scanned color image;

performing exposure correction of the image using the average color value data and exposure calibration data;

performing chromatic correction of the image using a subject failure suppression boundary following the exposure correction;

generating image correction data representative of the exposure correction and the chromatic correction;

generating reconstruction lookup tables (LUTs) based on the color correction data and the average color value data, each of the reconstruction LUTs representing a curve for reconstruction of one of the RGB color channels for the image; and

applying each of the reconstruction LUTs independently for the respective RGB color channels to produce a reconstructed color image.

16. The method of claim **15**, further comprising:

producing the average RGB color value data by:

histogram information representative of a distribution of RGB color values within the scanned color image, and

determining average RGB color values within the image based on the histogram information;

converting the average RGB color values to HSL coordinate values; and

performing the exposure correction of the image using the HSL coordinate values and the exposure calibration data.

17. The method of claim **16**, wherein each of the reconstruction LUTs is a preliminary reconstruction LUT, and applying the reconstruction LUTs includes:

adjusting each of the preliminary reconstruction LUTs by gamma correction based on the minima, maxima, and midpoint of the reconstruction curve;

applying a shaping function to each of the adjusted preliminary reconstruction LUTs to thereby generate respective final reconstruction LUTs; and

applying the final reconstruction LUTs to produce a reconstructed color image.

18. The method of claim **16**, wherein each of the reconstruction LUT is a preliminary reconstruction LUT, and applying the reconstruction LUTs includes:

selecting a target color value;

adjusting each of the preliminary reconstruction LUTs to map the average RGB color value to the target color value and thereby generate respective final reconstruction LUTs; and

applying the final reconstruction LUTs to produce a reconstructed color image.

19. The method of claim **16**, further comprising selecting the exposure calibration data based on the HSL coordinate values and a type of the film from which the color image was scanned.

20. The method of claim **19**, further comprising selecting the exposure calibration data by:

selecting a set of the exposure calibration data corresponding to the type of film from which the color image was scanned;

determining whether the image was over-exposed, under-exposed, or normally exposed by comparing the HSL coordinate values to reference values; and

selecting a subset of the exposure calibration data based on whether the image was over-exposed, under-exposed, or normally exposed.

21. The method of claim **20**, further comprising performing the exposure correction by:

adjusting the HSL lightness values for the image relative to HSL lightness values specified by the exposure calibration data; and

adjusting HSL color values for the image relative to HSL color values specified by the exposure calibration data.

22. The method of claim **16**, wherein the exposure calibration data includes multiple sets of exposure calibration data, each of the sets corresponding to a type of film from which the image was scanned and an exposure level of the image.

23. The method of claim **16**, further comprising scanning the image such that each of the RGB color values has a color resolution of n bits, and reducing the color resolution of the RGB color values to m bits following the application of the image correction data to the image to produce the corrected color image.

24. A system for reconstructing a digital color image scanned from film, the system comprising:

means for producing average RGB color value data for the scanned color image;

means for performing exposure correction of the image using the average color value data and exposure calibration data;

means for performing chromatic correction of the image using a subject failure suppression boundary following the exposure correction;

means for generating image correction data representative of the exposure correction and the chromatic correction;

means for generating reconstruction lookup tables (LUTs) based on the color correction data and the average color value data, each of the reconstruction lookup tables representing a curve for reconstruction of one of the RGB color channels for the image; and

means for applying each of the reconstruction LUTs independently for the respective RGB color channels to produce a reconstructed color image.

25. The system of claim **24**, wherein the means for producing the average color value data produces histogram information representative of a distribution of RGB color values within the scanned color image, and determines average RGB color values within the image based on the histogram information, the system further comprising means for converting the average RGB color values to HSL coordinate values, wherein the means for performing the exposure correction of the image uses the HSL coordinate values and the exposure calibration data.

26. The system of claim **25**, wherein each of the reconstruction LUTs is a preliminary reconstruction LUT, and the means for applying the reconstruction LUTs includes:

means for adjusting each of the preliminary reconstruction LUTs by gamma correction based on the minima, maxima, and midpoint of the reconstruction curve;

means for applying a shaping function to each of the adjusted preliminary reconstruction LUTs to thereby generate respective final reconstruction LUTs; and

means for applying the final reconstruction LUTs to produce a reconstructed color image.

27. The system of claim 25, wherein each of the reconstruction LUTs is a preliminary reconstruction LUT, and the means for applying the reconstruction LUTs includes:

means for selecting a target color value;

means for adjusting each of the preliminary reconstruction LUTs to map the average RGB color value to the target color value and thereby generate respective final reconstruction LUTs; and

means for applying the final reconstruction LUTs to produce a reconstructed color image.

28. The system of claim 25, further comprising means for selecting the exposure calibration data based on the HSL coordinate values and a type of the film from which the color image was scanned.

29. The system of claim 25, wherein the means for selecting the exposure calibration data includes:

means for selecting a set of the exposure calibration data corresponding to the type of film from which the color image was scanned;

means for determining whether the image was over-exposed, under-exposed, or normally exposed by comparing the HSL coordinate values to reference values; and

means for selecting a subset of the exposure calibration data based on whether the image was over-exposed, under-exposed, or normally exposed.

30. The system of claim 29, wherein the means for performing the exposure correction includes:

means for adjusting the HSL lightness values for the image relative to HSL lightness values specified by the exposure calibration data; and

means for adjusting HSL color values for the image relative to HSL color values specified by the exposure calibration data.

31. The system of claim 25, wherein the exposure calibration data includes multiple sets of exposure calibration

data, each of the sets corresponding to a type of film from which the image was scanned and an exposure level of the image.

32. The system of claim 25, further comprising means for scanning the image such that each of the RGB color values has a color resolution of n bits, and means for reducing the color resolution of the RGB color values to m bits following the application of the image correction data to the image to produce the corrected color image.

33. A method for correcting a digital color image scanned from film, the method comprising:

producing average color value data for the scanned color image;

performing exposure correction of the image using the average color value data and exposure calibration data;

performing chromatic correction of the image using a subject failure suppression boundary following the exposure correction;

generating image correction data representative of the exposure correction and the chromatic correction; and

applying the image correction data to the image to produce a corrected color image.

34. A system for correcting a digital color image scanned from film, the system comprising:

means for producing average color value data for the scanned color image;

means for performing exposure correction of the image using the average color value data and exposure calibration data;

means for performing chromatic correction of the image using a subject failure suppression boundary following the exposure correction;

means for generating image correction data representative of the exposure correction and the chromatic correction; and

means for applying the image correction data to the image to produce a corrected color image.

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US005929866A

United States Patent [19]

Arnold

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[45] **Date of Patent:** ***Jul. 27, 1999**

[54] **ADJUSTING CONTRAST IN ANTI-ALIASING**

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[73] Assignee: **Adobe Systems, Inc**, Mountain View, Calif.

[*] Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

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[52] U.S. Cl. 345/471
[58] Field of Search 395/167, 172, 395/132, 169, 170, 131, 171; 345/471

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Primary Examiner—Anton Fetting
Attorney, Agent, or Firm—Fish & Richardson P.C.

[57] **ABSTRACT**

A method and apparatus for processing a character for anti-aliased display on a raster output device. A set of density values is computed for a set of raster positions to represent the character and the density values of the set are scaled to extend their range upward toward a maximum density value, whereby generally at least one of the density values of the set becomes the maximum density value. In one embodiment, the set of density values is computed from a rendering of the character at resolution higher than the resolution of the output device. In another embodiment, the character is created by a font having font metrics including a reference dimension, and the density values are scaled by computing adjusted values as a non-decreasing function of the original values, the function being defined to compute a maximum adjusted density value for at least one non-maximum density value.
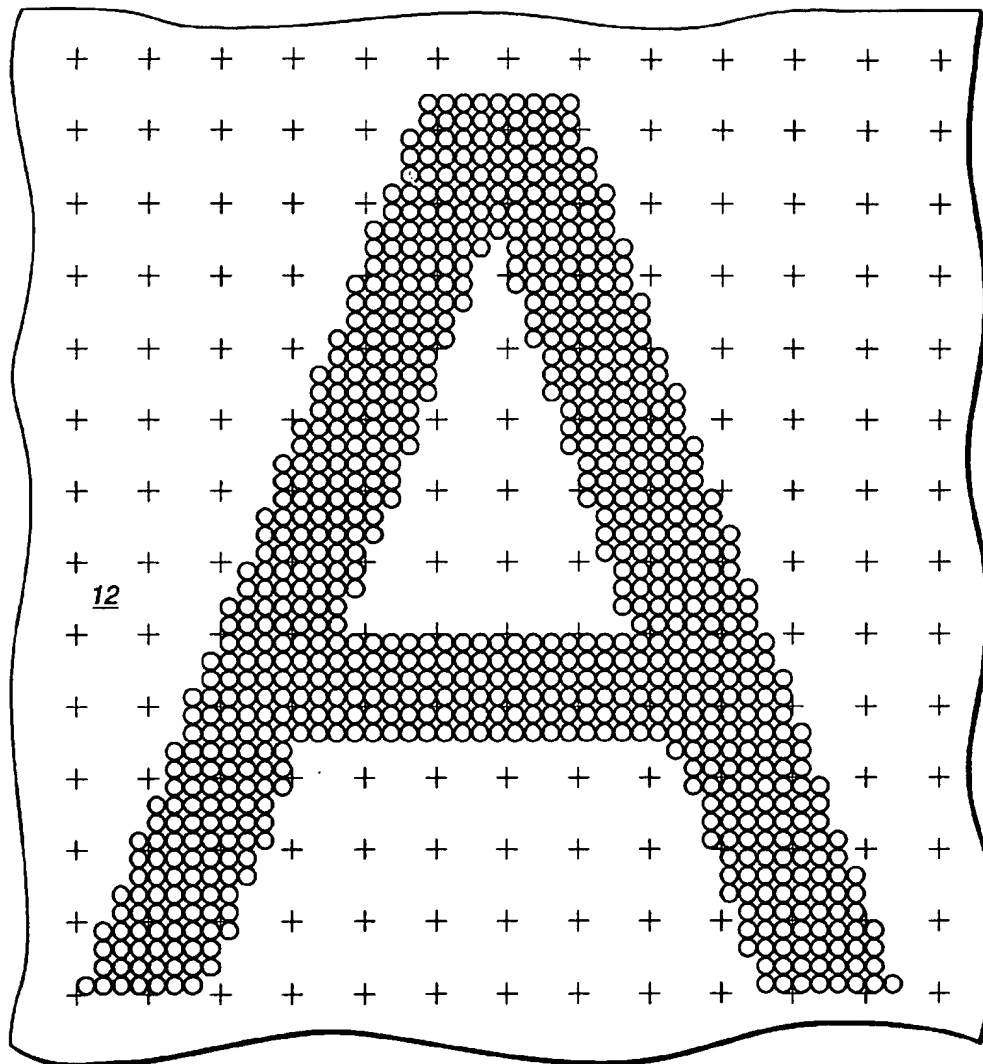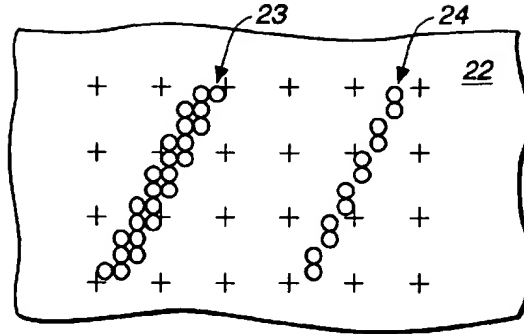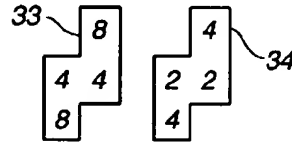
24 Claims, 6 Drawing Sheets
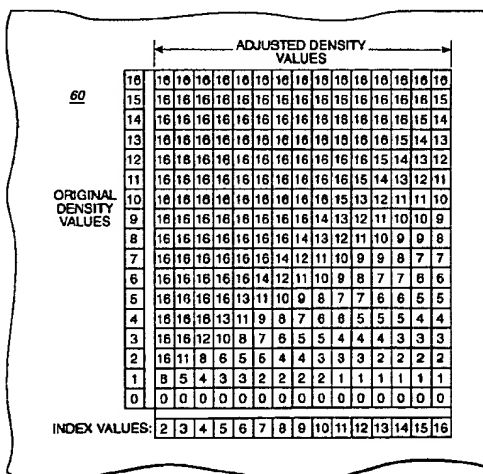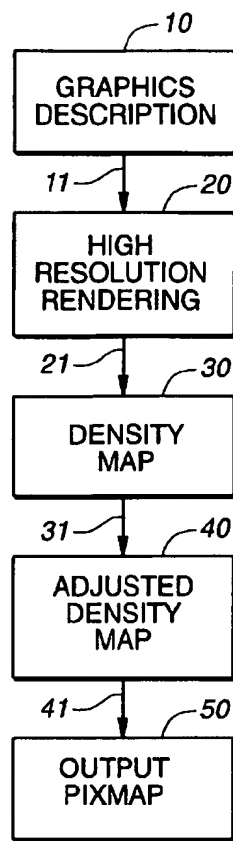
FIG._1a
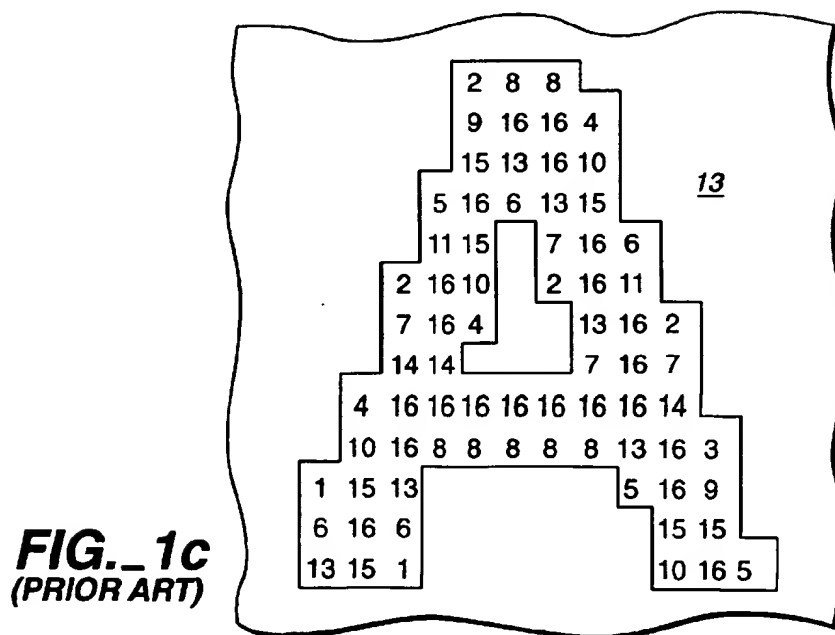
FIG._1c
(PRIOR ART)

FIG._1b *(PRIOR ART)*
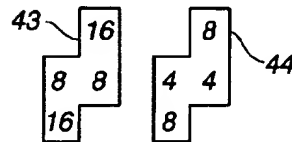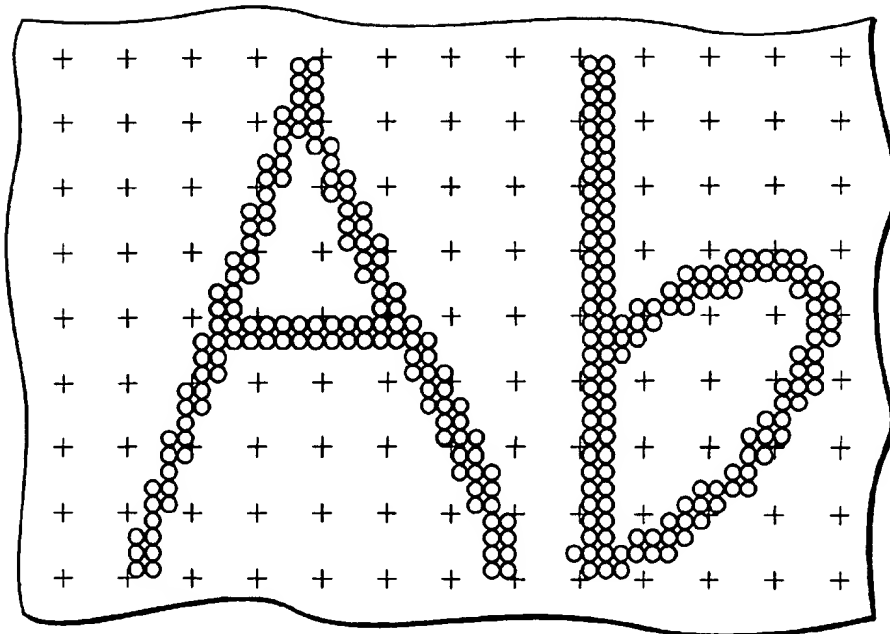
FIG._2
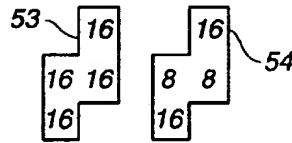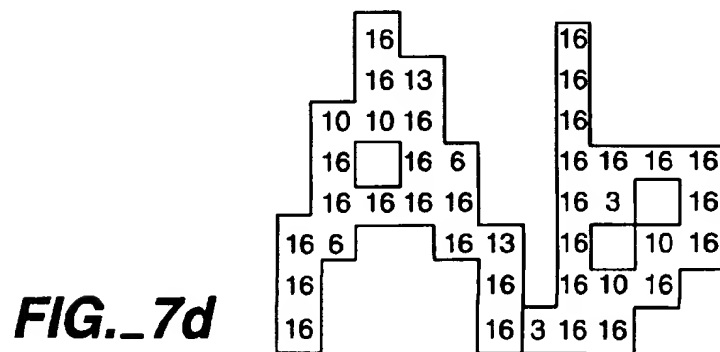
FIG._3

FIG._4

FIG._5

FIG._7a

ADJUSTED DENSITY VALUES →

_60_

ORIGINAL DENSITY VALUES

Orig.	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
15	16	16	16	16	16	16	16	16	16	16	16	16	16	16	15
14	16	16	16	16	16	16	16	16	16	16	16	16	16	15	14
13	16	16	16	16	16	16	16	16	16	16	16	16	15	14	13
12	16	16	16	16	16	16	16	16	16	16	16	15	14	13	12
11	16	16	16	16	16	16	16	16	16	16	15	14	13	12	11
10	16	16	16	16	16	16	16	16	16	15	13	12	11	11	10
9	16	16	16	16	16	16	16	16	14	13	12	11	10	10	9
8	16	16	16	16	16	16	16	14	13	12	11	10	9	9	8
7	16	16	16	16	16	16	14	12	11	10	9	9	8	7	7
6	16	16	16	16	16	14	12	11	10	9	8	7	7	6	6
5	16	16	16	16	13	11	10	9	8	7	7	6	6	5	5
4	16	16	16	13	11	9	8	7	6	6	5	5	5	4	4
3	16	16	12	10	8	7	6	5	5	4	4	4	3	3	3
2	16	11	8	6	5	5	4	4	3	3	3	2	2	2	2
1	8	5	4	3	3	2	2	2	2	1	1	1	1	1	1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

INDEX VALUES: 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

FIG._6

FIG._7b

DENSITY:	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
ADJUSTED DENSITY:	0	3	6	10	13	16	16	16	16	16	16	16	16	16	16	16	16

FIG._7c

FIG._7d

FIG._8

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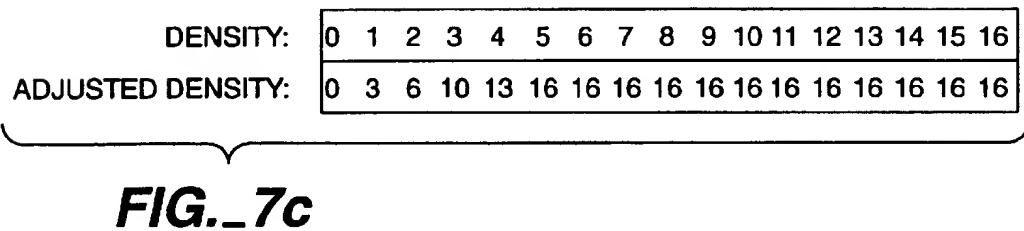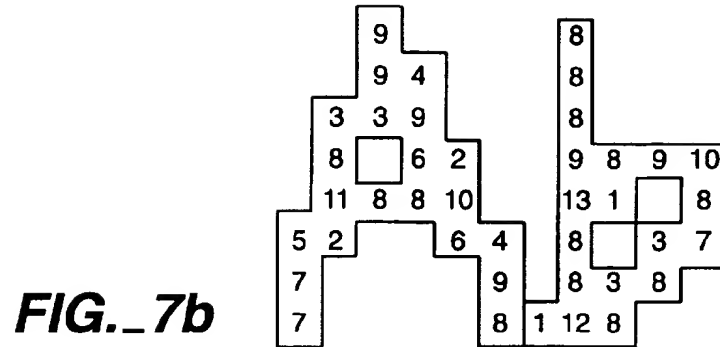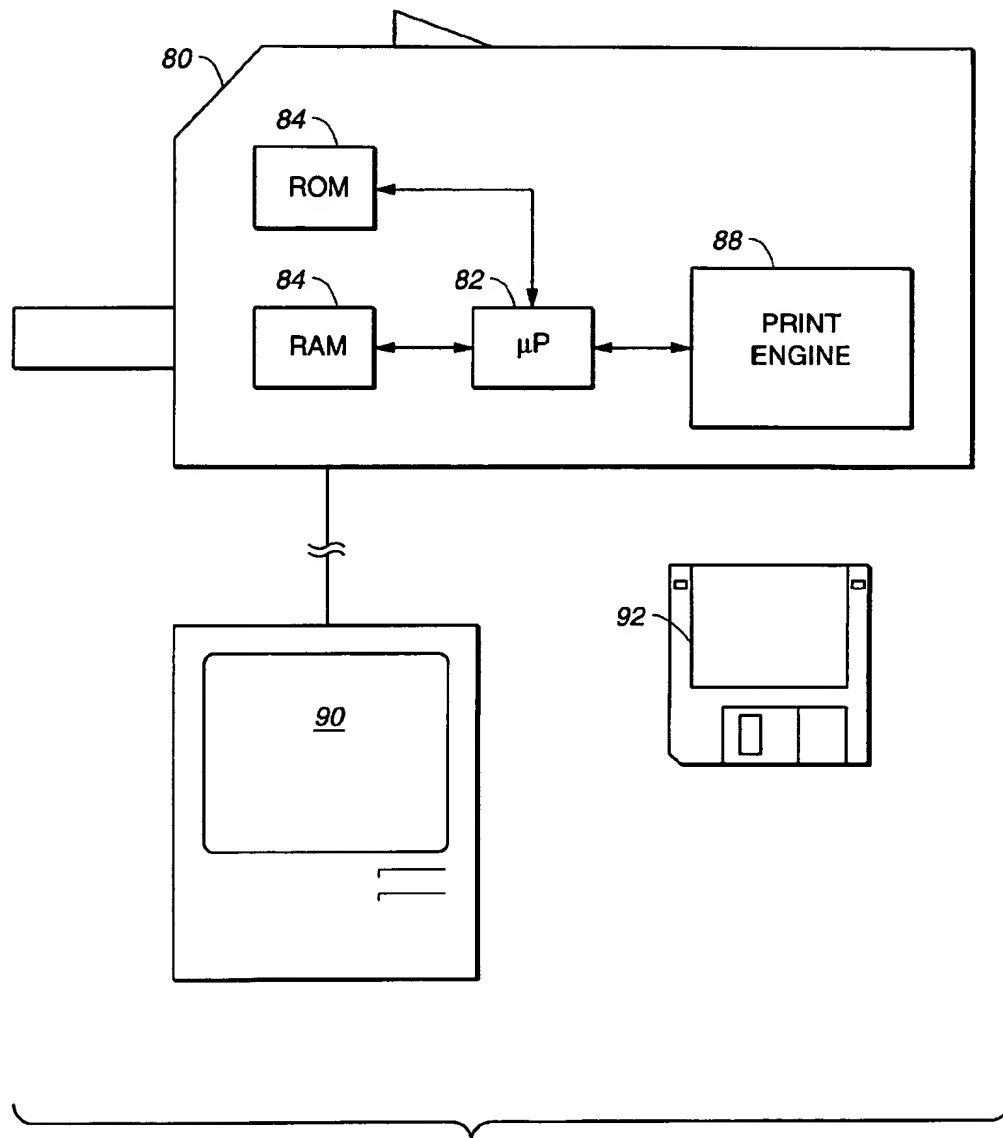
ADJUSTING CONTRAST IN ANTI-ALIASING

BACKGROUND OF THE INVENTION

CROSS REFERENCE TO RELATED APPLICATIONS

The present invention is related to commonly assigned U.S. patent application Ser. No. 08/547,562, filed on Oct. 23, 1995 and entitled METHOD AND APPARATUS FOR RENDERING CHARACTERS, the disclosure of which is incorporated herein by this reference.

FIELD OF THE INVENTION

The invention relates to the computer-implemented rendering of font characters for display on raster output devices, and more particularly, to the display of anti-aliased character strokes for small characters.

BACKGROUND

An alphabet of characters with a particular design is called a "typeface". A "font" is a collection of instructions that a processor, such as a microprocessor controlling a printer, can use to create text (the characters of the alphabet) in a particular typeface. A font used in a computer is generally stored in one or more disk files. A font used by a printer is generally stored in a read-only memory, downloaded from some computer into printer random access memory, or loaded from a disk attached to the printer directly or remotely.

As used herein, a character may be any form of monochromatic character, number, symbol, icon, graphic, or the like that can be displayed as a graphical element on an output device. A text character consists of at least one stroke, which may be straight or curved and has a nonzero width. The specific appearance of a character on an output device is created by its font. Present-day fonts, such as PostScript™ fonts available from Adobe Systems Incorporated of Mountain View, Calif., generally include a graphics description providing the outline of the character as it is to be displayed, an are for that reason referred to as outline fonts.

A character is generally presented on an output device as an image consisting of pixels (picture elements) arranged in the rows and columns of a raster. If a pixel on the output device has only two possible tone values (e.g., a background color such as white and a foreground color such as black, for normal text documents), the image pixels can be encoded each as a single bit. If the output device can have more than two tone values at each pixel position (e.g., tones ranging from the background color, through blends of the background and foreground colors, to the foreground color), more than one bit must be used to represent the possible pixel values.

Computers and computer printers generally scan-convert outline font characters for display on raster output devices. The result of this interpretation or rendering of the characters results in a bit map of one-bit pixels or in a run array of scan lines indicating the positions of background-foreground transitions. The rendering may be thought of as providing a set of pixels each representing one of two colors: a background color or a foreground color. (The term "pixel" is used for both the physical output viewed on a printed page or a display monitor, for example, and for the data element in a computer; however, the meaning will be clear from the context.) For characters elements having edges that are not aligned with the raster of the output device, the edges of the

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displayed image may have a jagged appearance. This effect is called aliasing.

The jagged edges can be smoothed by anti-aliasing techniques such as those explained in "Computer Graphics, Principles and Practice", Second Edition, by James D. Foley et al. One type of anti-aliasing that can be performed for output devices capable of displaying more than two tones is to soften a jagged edge by shading pixels along the edge.

Anti-aliasing techniques have provided good results for large characters. However, they have encountered problems with smaller characters. As type size is reduced relative to output device resolution, a character's strokes may be reduced in width to less than one output pixel. When anti-aliasing shades such narrow strokes, the strokes tend to fade, which can make the resulting output hard to read.

SUMMARY OF THE INVENTION

In general, in one aspect, the invention provides a computer-implemented method for processing a character for anti-aliased display on a raster output device. The method includes computing a set of density values for a set of raster positions to represent the character and scaling the density values of the set to extend their range upward toward a maximum density value, whereby generally at least one of the density values of the set becomes the maximum density value. In another aspect, the set of density values is computed from a rendering of the character at resolution higher than the resolution of the output device. In another aspect, the character is created by a font having font metrics including a reference dimension, and the density values are scaled by computing adjusted values as a non-decreasing function of the original values, the function being defined to compute a maximum adjusted density value for at least one non-maximum density value.

In general, in another aspect, the invention provides a computer-implemented method for processing a character for anti-aliased display on a raster output device having an output pixel position, the character being created at a type size by a font having font metrics including a reference dimension. The method includes rendering the character at a resolution higher than the output resolution, computing an original density value for the output pixel position from the rendering, and computing an adjusted density value by applying an adjustment function to the original density value, the adjustment function being defined to compute a maximum adjusted density value when applied to a range of one or more non-maximum original density values. In another aspect, the step of rendering the character generates bit values of a bit map or of a set of run array lines having a resolution higher than the output resolution, and the original density value is computed as a function of bit values generated in the rendering step. In another aspect, the original density value is computed as a sum of bit values generated in the rendering step for positions that correspond to the output pixel position. In another aspect, the reference dimension is a scalable measure of a standard stem width for a vertical or horizontal stem.

In another aspect, the method includes computing a pixel value for the output pixel position from the adjusted density value, where the pixel value is computed by blending a foreground color and a background color according to the adjusted density value, and where foreground and background color are a chromatic color or a gray scale value. In another aspect, the method includes comparing the scaled reference dimension to a threshold value and bypassing the step of adjusting the density value if the threshold value is

exceeded. In another aspect, the method includes caching the adjusted density value for the event that anti-aliasing needs to be performed again for the character of the font. In another aspect, the adjustment function is a function of the original density value and an index value, the adjustment function being defined to compute a maximum adjusted density value when applied to an original density values that is greater than or equal to the index value. In another aspect, the adjustment function uses the index value to select a precomputed table that maps a density derived from the higher-resolution rendering to a value, where the map defines a non-decreasing function. In another aspect, the index value is approximately a maximum density value times the reference dimension scaled to the type size divided by a threshold stem width. In another aspect, the threshold stem width is in the range of approximately 1.0 to 2.3 pixels.

In general, in another aspect, the invention provides an anti-aliasing method for displaying a character on a raster output device having an output resolution, including, in general, steps of rendering the character, computing a set of density values, scaling the density values, computing pixel values for output device pixel positions, and displaying the pixel values on the output device.

In general, in another aspect, the invention provides a computer program storage device—such as a read-only, semiconductor memory device, such as an EPROM, or a magnetic disk, a magneto-optical disk, or a CD-ROM disk—tangibly embodying a set of computer-readable computer program instructions including, in various aspects, instructions for practicing the methods of the invention as are described here.

The invention has a number of advantages.

For example, the invention provides small characters that are readable and have little fading or distortion. Use may be made of the invention without affecting the anti-aliasing of large characters and without changing the overall inked appearance of a page.

For a fuller understanding of the nature and further advantages of the invention, reference should be made to the detailed description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of the specification, schematically illustrate specific embodiments of the invention and, together with the general description given above and the detailed description of the embodiments given below, serve to explain the principles of the invention.

FIG. 1a is flow diagram of a method of rendering characters using an anti-aliasing technique according to the present invention.

FIGS. 1b and 1c illustrate a typical prior art method for anti-aliasing a character.

FIG. 2 illustrates a high resolution bit map for two character strokes and their neighboring area.

FIG. 3 illustrates a density map for the bit map of FIG. 2.

FIGS. 4 and 5 each illustrate an adjusted density map for the bit map of FIG. 2 according to the present invention.

FIG. 6 is a table illustrating a mapping of original density values to adjusted density values according to the present invention.

FIG. 7a illustrates a high resolution bit map.

FIG. 7b illustrates a density map created from the high resolution bit map of FIG. 7a.

FIG. 7c is an adjustment map extracted from the table of FIG. 6, based on an index value of five.

FIG. 7d is an adjusted density map, resulting from applying the adjustment map of FIG. 7c to the density map of FIG. 7b.

FIG. 8 is a diagram illustrating apparatus embodying the present invention.

DETAILED DESCRIPTION

Referring to FIG. 1, in a process for preparing a character for display on an output device (such as a monitor or printer) according to the present invention, a graphics description 10 for the character is rendered into a high resolution rendering 20 (such as a high resolution bit map) having a higher resolution than is supported by the output device. (Step 11) The graphics description 10 is generally an outline font program. In other embodiments, the graphics description may take other forms, including the form of a high resolution bit map, in which case the rendering step (step 11) is not necessary and the resolution of the rendering 20 may be taken as that given by the graphics description. An outline font graphics description rendered to any resolution by a rendering program available from a variety of sources, including Adobe Systems. As used here, resolution refers to the spacial density of pixels in an internal computer representation or on an output device, which is often expressed in terms of dots per inch.

image as input .

From the high resolution rendering 20, a density map 30 is created at the output device resolution. (Step 21) Each density element of the density map 30 is computed from a plurality of elements (for example, bits) in the high resolution rendering 20. In one embodiment, a box filter function illustrated in FIGS. 2 and 3, the value of each density element is computed as the sum of the bit values of the high resolution bit map bit positions corresponding to the density element.

The value assigned to a density element may be thought of as representing a tone, ranging from a background color to a foreground color. Having the same resolution, each density element of the density map corresponds to a pixel position on the output device, and the value of a density element may be used to determine the tone at the corresponding output pixel. For example, for a density element having a value of zero, the tone of the output pixel may be set to a background color; for a density element having a maximum value, the tone of the output pixel may be set to a foreground color; and for a density element having an intermediate value, the tone of the output pixel will be a blend of the background and foreground colors.

An adjusted density map 40 is created from the density map 30 by adjusting the density map values to compensate for any fading expected to occur. (Step 31) This step may be performed on the density map as a whole after it is developed, or on parts of it as it is being developed.

Finally, an output pixel map or pixmap map 50 is computed from the adjusted density map 40 by assigning a corresponding output pixel value to each density element. (Step 41) This step may be performed on the adjusted density map as a whole after it is developed, or on parts of it as it is being developed, or in parallel with the step of creating a density map. Thus, it is not necessary that the high resolution rendering 20 be completed before the creation of the density map 30 is begun, nor is it necessary that the creation of the density map 30 be completed before the creation of adjusted density map 40 is begun, nor is it necessary that the creation of the adjusted density map 40 be

completed before the creation of the output pixel map 50 is begun. Moreover, data structures may be used in practicing the invention other than the bit maps, pixel maps, and tables that are used here for the sake of illustration.

Referring to FIGS. 1b and 1c, in a prior art method for anti-aliasing, the character is rendered as a bit map 12 at a resolution higher than that supported by the output device. Then, a density map 13 is computed at the same resolution as the output device. (For clarity, zero values are not shown in the density map.) Each element of the density map is computed as a function of numerous bits in the high resolution bit map 12, in a process called super sampling. The specific function used to combine the samples is called the filter. Then, a device pixel map is computed for output. Each device pixel corresponds to one density element. The color or value of the device pixel is computed by blending a foreground color and background color according to the corresponding density element. For zero density, the result is equal to the background color. For maximum density, the result is equal to the foreground color, and at intermediate densities the color is a blend of the two. It will be understood that the densities described here run linearly from a minimum to a maximum value, and that in generating output for a typical color output device, such a color monitor, system non-linearities must be taken into account to achieve the desired visual effect.

Exemplary bit maps and density maps illustrating the present invention are shown in FIGS. 2 through 5. FIG. 2 shows a high resolution bit map 22 for two character strokes 23 and 24 and a neighboring area. The circles in the figure represent the bits in a high resolution bit map for the character strokes and the crosses define the lower output resolution supported by an output device. In this example, the high resolution bit map has four times the resolution of the output device in both the x and y directions, and each density element and each output pixel of the output device corresponds to sixteen bits arranged in 4x4 formation on the high resolution bit map. The left stroke 23 has a stroke width of 0.5 pixels; the right stroke 24, of 0.25 pixels (at the output device resolution).

The density maps 33 and 34 shown in FIG. 3 result from applying a filter function to the graphical elements represented in FIG. 2. A variety of filter functions may be used, and the specific function used in this example is a box filter function, which gives equal weight to each of the sixteen high resolution bit map bits corresponding to a density element, and computes a value for that density element as the total number of high resolution bit map bits within the corresponding area. It should be noted, however, that a filter function may take as input overlapping ranges of bits in the high resolution bit map, in which case a value of one high resolution bit can affect more than one density element and its corresponding output pixel.

Referring to FIG. 3, the density values of the adjusted density maps 43 and 44 are adjusted from the corresponding density maps 33 and 34 (FIG. 3) in order to ensure adequate contrast in situations where fading is likely to occur. (Step 31) Adjustment can be made by a variety of methods. The adjustment function used in calculating the values of the adjusted density map 43 and 44 simply multiplies each original density value by a factor of two, with the result being limited to a maximum value of sixteen. Similarly, the adjustment function used to create the adjusted density maps 53 and 54 shown in FIG. 5 multiplies each original density value by a factor of four, with the same limiting maximum value of sixteen. The adjustment used in FIG. 4 is sufficient to cause some density values in the wider stroke 43 to reach

a maximum value, but none of those of the narrower stroke 44. Thus, if stroke 44 were of the standard stem width, for example, the adjustment illustrated in FIG. 5 would provide better contrast than the adjustment of FIG. 4. Furthermore, if it were desired to have a pixel of a maximum density value on each scan line, the adjustment of FIG. 5 would be selected over that of FIG. 4 for a standard stem width of stroke 23 (stroke 53 in FIG. 5).

Adjusted density maps 40 may optionally be cached, to permit re-use of the calculation of the adjusted density values for an output device resolution, even if the output device bit depth changes.

As has been mentioned, the original density values are adjusted to increase contrast in situations where anti-aliasing is likely to result in fading. In one embodiment, the density map 30 is adjusted only when it appears that a fading problem may exist. This situation may be identified by comparing a reference dimension of the character font (such as a standard stem width scaled to the type size at which the character is being rendered) to a stroke width threshold. The threshold may be obtained in a variety of ways: it may be predetermined, for example, or it may be set by user input. A threshold value found to work well is 1.5 output pixels. When the threshold value is equal to or greater than the reference dimension scaled to the output type size, the values in the original density map are adjusted to increase the density values assigned to some of the output pixels, as will be described.

A font typically has font metrics, which generally include scalable dimensions such as a standard stem width for a character, which is scaled to the type size at which the font is rendered. (A stem in a font is a stroke or a part of a stroke, typically aligned vertically or horizontally.) A scaled stem width, such as a scaled standard horizontal or vertical stem width, of a font generally provides a good estimate of stroke width. In one embodiment, the density values for output pixels at the core of a character stroke of the standard width are generally adjusted to a maximum density value, resulting in output characters that retain high contrast, avoid fading at small type sizes relative to the output raster resolution, and are therefore easier to read than they would be without the adjustment.

Density map adjustment may be made using a table 60 such as is illustrated in FIG. 6, which maps an original density value and an index to an adjusted density value. Note the generally diagonal structure, from lower left to upper right, of this table. Note also that in this example, the index value is the same as the lowest original density value that is mapped to 16, representing a maximum output density.

In this embodiment, the index is calculated as follows:

$$\text{index} = \text{round}\left[20 \times \frac{\text{scaled stroke width} + 1/4}{\text{threshold} + 1/4}\right] - 4$$

with the result clipped to the range of 2 to 16. (The "scaled stroke width" and "threshold" are both in units of output device pixels. The scaled stroke width is the standard stroke width reference dimension (in the units of the character space) scaled to the output type size.) Other functions may be used to map the original density values into a larger range of adjusted density values. The particular mapping function selected will vary depending on the desired result.

This embodiment will be further described with reference to the high resolution rendering illustrated in FIG. 7a. FIG. 7b illustrates the density map resulting from application of

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the box filter function described above. Assuming a scaled standard stem width of 0.5 and a threshold of 1.5, the index calculated in accordance the function above is 5. For an index of 5, the table shown in FIG. 6 defines an adjustment function mapping original density values to adjusted density values, and the columns of interest have been isolated in the adjustment map shown in FIG. 7c.

FIG. 7d shows the result of applying this adjustment to the original density map shown in FIG. 7b. The adjusted density values shown in FIG. 7d will result in an output image having increased contrast between the tones of character strokes of standard width and the background color, thereby reducing any fading that otherwise may have occurred.

The threshold value of 1.5 pixels has been found to give pleasing results for a range of fonts for the English alphabet. The use of this threshold value is illustrated in FIG. 7d. A higher value, empirically on the order of 2.25 pixels, generally results in standard width strokes having a maximum density pixel on each scan line through which the stroke passes, regardless. A lower value of approximately 1.0 gives that result only for standard width strokes that are substantially horizontal or vertical.

Referring to FIG. 8, it will be well understood that the methods described here may be readily implemented in hardware or in a computer program product tangibly embodied in a computer program storage device for execution by a computer processor. A present-day printer 80 implementing an interpreter for a page description language, such as PostScript, includes a microprocessor 82 for executing program instructions (including font instructions) stored on a printer random access memory 84 and a printer read-only memory (ROM) 84 and controlling a printer print engine 88. The essential elements of a computer are a processor for executing instructions and a memory, and these will be found in desktop computer 90 and other computers suitable for executing computer programs implementing the methods described here, which may be used in conjunction with any print engine, display monitor, or other raster output device capable of producing color or gray scale pixels. Generally, a computer will include both a read-only memory and a random access memory. Storage devices suitable for tangibly embodying computer program instructions implementing the methods described here include all forms of nonvolatile memory, including semiconductor memory devices, such as EPROM, EEPROM, and flash memory devices, magnetic disks such as internal hard disks and removable disks 92, magneto-optical disks, and CD-ROM disks.

The present invention has been described in terms of specific embodiments. The invention, however, is not limited to these specific embodiments. Rather, the scope of the invention is defined by the following claims, and other embodiments are within the scope of the claims. For example, various anti-aliasing techniques may be used without diminishing the advantages of the present invention. In one variation, rather than using a rendering in a higher resolution bit map, a run array made up of scan lines at the higher resolution that identify the locations of the transitions may be used instead.

What is claimed is:

1. A computer-implemented method for processing a character for anti-aliased display on a raster output device where the character is created at a type size by a font having font metrics including a standard stem width, the method comprising:

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computing a set of density values to provide one density value for each of a set of raster positions to represent the character on the raster output device; and

comparing (i) the standard stem width scaled to the type size to (ii) a threshold value, and if the threshold value is exceeded increasing at least one of the density values in the computed set of density values, thereby compensating for fading that may occur in the display of the character on the raster output device.

2. The method of claim 1 where the output device has a resolution and the set of density values is computed from a rendering of the character at resolution higher than the resolution of the output device.

3. The method of claim 1 where

the density values are scaled by computing adjusted values as a non-decreasing function of the original values, the function being defined to compute a maximum adjusted density value for at least one non-maximum density value.

4. A computer-implemented method for processing a character for anti-aliased display on a raster output device having an output resolution and one or more output pixel positions for display of the character, the character being created at a type size by a font having font metrics including a reference dimension, the method comprising:

rendering the character at a resolution higher than the output resolution;

computing a set of original density values, one for each output pixel position used to display the character, from the rendering, wherein the set of original density values includes a highest density value;

computing an adjusted density value for at least one computed original density value by applying an adjustment function to the original density value, the adjustment function being defined to compute an adjusted density value having a maximum value when the adjustment function is applied to the highest density value; and

comparing (i) the reference dimension scaled to the type size to (ii) a threshold value, and bypassing the step computing an adjusted density value if the threshold value is exceeded.

5. The method of claim 4 where

the step of rendering the character generates bit values of a bit map or of a set of run array lines having a resolution higher than the output resolution; and

the original density value is computed as a function of bit values generated in the rendering step.

6. The method of claim 5 where

the original density value is computed as a sum of bit values generated in the rendering step for positions that correspond to the output pixel position.

7. The method of claim 4 where the reference dimension is a scalable measure of a standard stem width for a vertical or horizontal stem.

8. The method of claim 4 further comprising:

computing a pixel value for the output pixel position from the adjusted density value, where the pixel value is computed by blending a foreground color and a background color according to the adjusted density value, and where foreground and background color are a chromatic color or a gray scale value; and

displaying pixel values on the raster output device.

9. The method of claim 4 further comprising the step of caching the adjusted density value for use if anti-aliasing needs to be performed again for the character of the font.

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10. A computer-implemented method for processing a character for anti-aliased display on a raster output device having an output resolution and one or more output pixel positions for display of the character, the character being created at a type size by a font having font metrics including a reference dimension, the method comprising:

rendering the character at a resolution higher than the output resolution;

computing a set of original density values, one for each output pixel position used to display the character, from the rendering, wherein the set of original density values includes a highest density value; and

computing an adjusted density value for at least one computed original density value by applying an adjustment function to the original density value, where the adjustment function is a function of the original density value and an index value and where the index value is approximately a maximum density value times the reference dimension scaled to the type size divided by a threshold stem width, the adjustment function being defined to compute a maximum value when applied to an original density value that is greater than or equal to the index value.

11. The method of claim 10 where

the adjustment function uses the index value to select a precomputed table that maps a density derived from the higher-resolution rendering to a value, where the table defines a non-decreasing function.

12. The method of claim 10 where the threshold stem width is in the range of approximately 1.0 to 2.3 pixels.

13. A storage device readable by a machine, tangibly embodying a set of computer-readable computer program instructions comprising instructions for processing a character for anti-aliased display on a raster output device where the character is created at a type size by a font having font metrics including standard stem width, the set of instructions comprising:

instructions for computing a set of density values for a set of raster positions to represent the character; and

instructions for comparing (i) the standard stem width scaled to the type size to (ii) a threshold value, and if the threshold value is exceeded increasing at least one of the density values of the set thereby compensating for fading that may occur in the display of the character on the raster output device.

14. The apparatus of claim 13 where the output device has a resolution and the instructions for scaling the set of density values computes from a rendering of the character at resolution higher than the resolution of the output device.

15. The apparatus of claim 13 where

the instructions for scaling the set of density values compute adjusted values as a non-decreasing function of the original values, the function being defined to compute a maximum adjusted density value for at least one non-maximum density value.

16. A storage device readable by a machine, tangibly embodying a set of computer-readable computer program instructions comprising instructions for processing a character for anti-aliased display on a raster output device having an output pixel position, the character being created at a type size by a font having font metrics including a reference dimension, the set of instructions comprising:

instructions for rendering the character at a resolution higher than the output resolution;

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instructions for computing a set of original density values, one for each output pixel position, from the rendering, wherein the set of original density values includes a highest density value;

instructions for computing an adjusted density value for at least one computed original density value by applying an adjustment function to the original density value, the adjustment function being defined to compute an adjusted density value having a maximum density value when the adjustment function is applied to the highest density value; and

instructions for comparing (i) the reference dimension scaled to the type size to (ii) a threshold value, and bypassing the step of computing an adjusted density value if the threshold value is exceeded.

17. The apparatus of claim 16 where

the instructions for rendering the character generates bit values of a bit map or of a set of run array lines having a resolution higher than the output resolution; and

the instructions for computing an original density value compute a function of bit values generated by the rendering instructions.

18. The apparatus of claim 17 where

the original density value is computed as a sum of bit values generated in the rendering step for positions that correspond to the output pixel position.

19. The apparatus of claim 16 where the reference dimension is a scalable measure of a standard stem width for a vertical or horizontal stem.

20. The apparatus of claim 16 further comprising:

instructions for computing a pixel value for the output pixel position from the adjusted density value, where the pixel value is computed by blending a foreground color and a background color according to the adjusted density value, and where foreground and background color are a chromatic color or a gray scale value; and

instructions for displaying pixel values on the raster output device.

21. The apparatus of claim 16 further comprising:

instructions for caching the adjusted density value for use if anti-aliasing needs to be performed again for the character of the font.

22. A storage device readable by a machine, tangibly embodying a set of computer-readable computer Program instructions comprising instructions for processing a character for anti-aliased display on a raster output device having an output pixel position, the character being created at a type size by a font having font metrics including a reference dimension, the set of instructions comprising:

instructions for rendering the character at a resolution higher than the output resolution;

instructions for computing a set of original density values, one for each output pixel position, from the rendering, wherein the set of original density values includes a highest density value; and

instructions for computing an adjusted density value for at least one computed original density value by applying an adjustment function to the original density value, the adjustment function is a function of the original density value and an index value and where the index value is approximately a maximum density value times the reference dimension scaled to the type size divided by a threshold stem width, the adjustment function being defined to compute a maximum density value when

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applied to an original density value that is greater than or equal to the index value.

23. The apparatus of claim 22 where

the adjustment function uses the index value to select a precomputed table that maps a density derived from the

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higher-resolution rendering to a value, where the table defines a non-decreasing function.

24. The apparatus of claim 22 where the threshold stem width is in the range of approximately 1.0 to 2.3 pixels.

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United States Patent [19]

Okada

[11] **Patent Number:** 5,852,468

[45] **Date of Patent:** Dec. 22, 1998

[54] **1-CHIP COLOR VIDEO CAMERA FOR GENERATING INTER-PIXEL COLOR SIGNAL COMPONENT BY INTERPOLATING PRIMARY COLOR SIGNALS FROM NEIGHBORING PIXELS**

[75] Inventor: **Hidefumi Okada**, Daito, Japan

[73] Assignee: **Sanyo Electric Co., Ltd.**, Japan

[21] Appl. No.: **604,482**

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[30] **Foreign Application Priority Data**

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[51] Int. Cl.⁶ .... $H04N \ 3/14$; $H04N \ 5/335$; $H04N \ 9/04$; $H04N \ 9/083$

[52] U.S. Cl. 348/272; 348/280

[58] Field of Search 348/272, 273, 348/280, 263, 625, 630, 717, 266, 268, 269, 277, 281, 282, 320, 321, 322, 323, 324, 624

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Assistant Examiner—Christopher Onuaku
Attorney, Agent, or Firm—Michaelson & Wallace; Peter L. Michaelson

[57] **ABSTRACT**

A 1-chip color video camera which provides a frequency characteristic that exhibits relatively little attenuation up to a high frequency range for a (green) signal and has a highest degree of contribution to brightness, and hence provides high resolution. The 1-chip color video camera has a color separation circuit for processing signals obtained from a solid-state image sensor wherein primary color filters of R(red), G and B(blue) are arranged mosaic-wise for respective pixels. Color signal components at a central portion of a pixel block consisting of four pixels of two rows by two columns on the solid-state image sensor are generated by interpolating color signal components of a plurality of neighboring pixels.
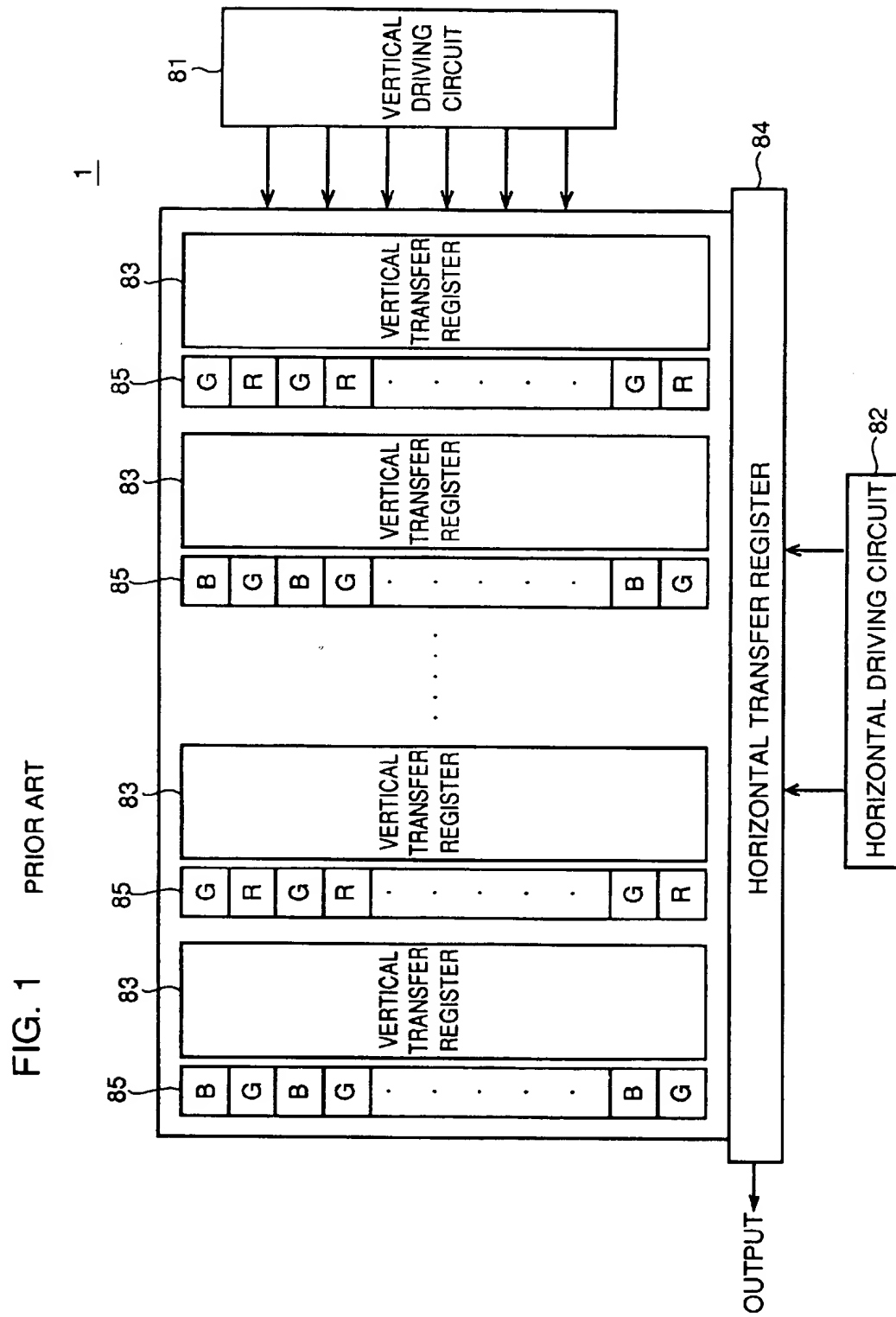
14 Claims, 8 Drawing Sheets

100

FIG. 1
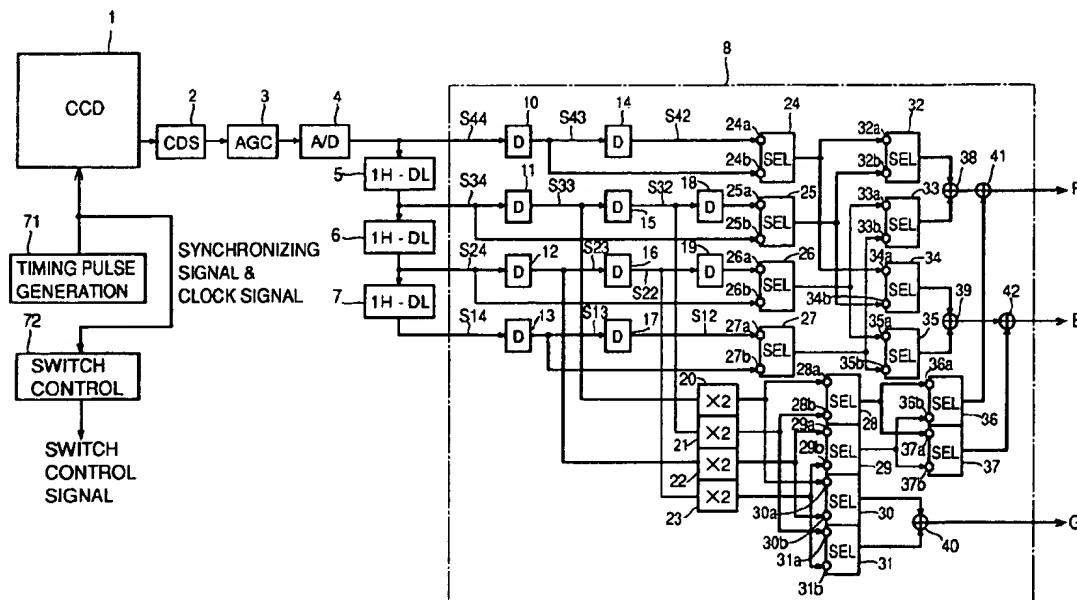
PRIOR ART

FIG. 2   PRIOR ART

B	G	B	G	B	G	B	G
G	R	G	R	G	R	G	R
B	G	B	G	B	G	B	G
G	R	G	R	G	R	G	R
B	G	B	G	B	G	B	G
G	R	G	R	G	R	G	R
B	G	B	G	B	G	B	G
G	R	G	R	G	R	G	R

~70

PRIOR ART
FIG. 3A

G	R	G
B	G	B
G	R	G

ARRANGEMENT
H1

PRIOR ART
FIG. 3B

	4	

WEGHT
COEFFICIENT
FOR G SIGNAL

PRIOR ART
FIG. 3C

	2	
	2	

WEGHT
COEFFICIENT
FOR R SIGNAL

PRIOR ART
FIG. 3D

2		2

WEGHT
COEFFICIENT
FOR B SIGNAL

PRIOR ART
FIG. 4A

R	G	R
G	B	G
R	G	R

ARRANGEMENT
H2

PRIOR ART
FIG. 4B

	1	
1		1
	1	

WEGHT
COEFFICIENT
FOR G SIGNAL

PRIOR ART
FIG. 4C

1		1
1		1

WEGHT
COEFFICIENT
FOR R SIGNAL

PRIOR ART
FIG. 4D

	4	

WEGHT
COEFFICIENT
FOR B SIGNAL

PRIOR ART
FIG. 5A

B	G	B
G	R	G
B	G	B

ARRANGEMENT
H3

PRIOR ART
FIG. 5B

	1	
1		1
	1	

WEGHT
COEFFICIENT
FOR G SIGNAL

PRIOR ART
FIG. 5C

	4	

WEGHT
COEFFICIENT
FOR R SIGNAL

PRIOR ART
FIG. 5D

1		1
1		1

WEGHT
COEFFICIENT
FOR B SIGNAL

PRIOR ART
FIG. 6A

G	B	G
R	G	R
G	B	G

ARRANGEMENT
H4

PRIOR ART
FIG. 6B

	4	

WEGHT
COEFFICIENT
FOR G SIGNAL

PRIOR ART
FIG. 6C

2		2

WEGHT
COEFFICIENT
FOR R SIGNAL

PRIOR ART
FIG. 6D

	2	
	2	

WEGHT
COEFFICIENT
FOR B SIGNAL
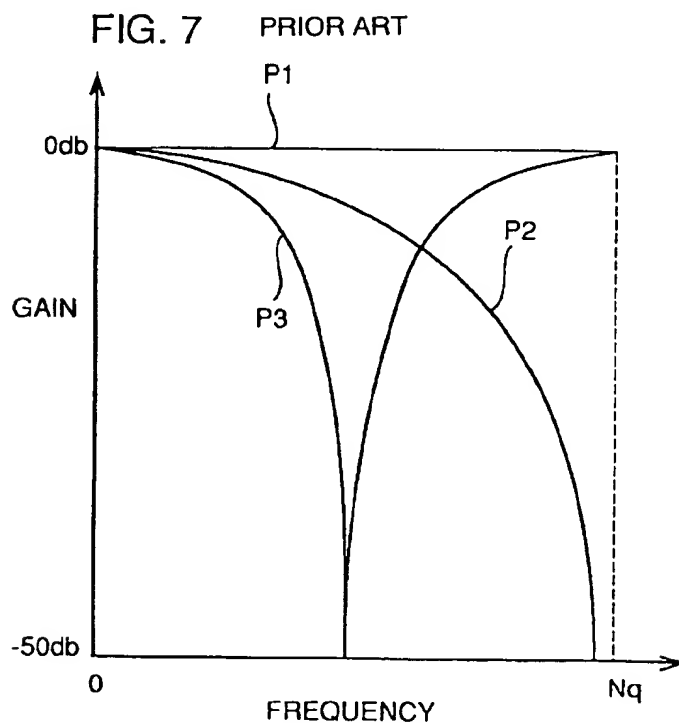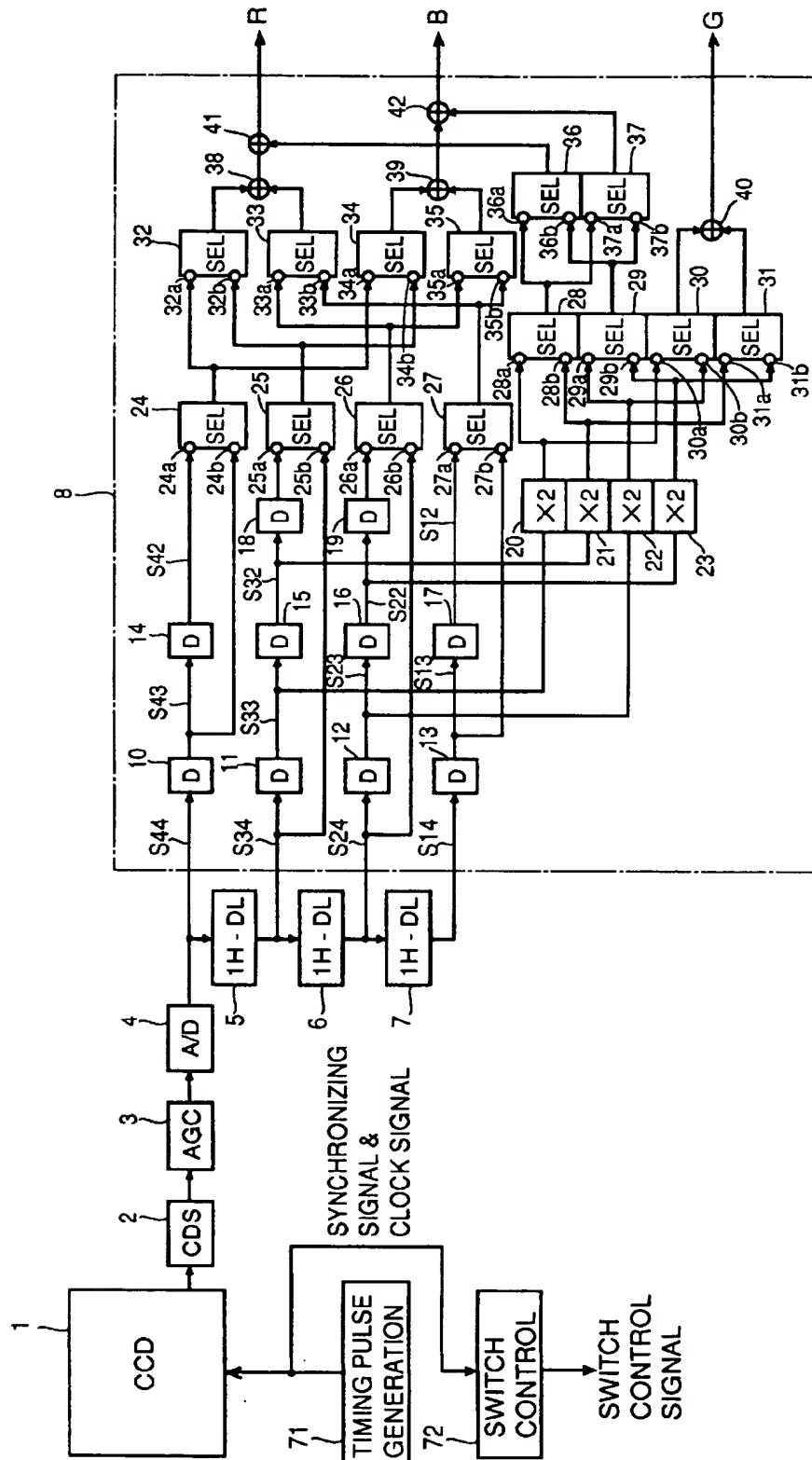
FIG. 7   PRIOR ART

FIG. 8

FIG. 9

FIG. 10A   FIG. 10B   FIG. 10C   FIG. 10D

ARRANGEMENT
1

WEGHT
COEFFICIENT
FOR G SIGNAL

WEGHT
COEFFICIENT
FOR R SIGNAL
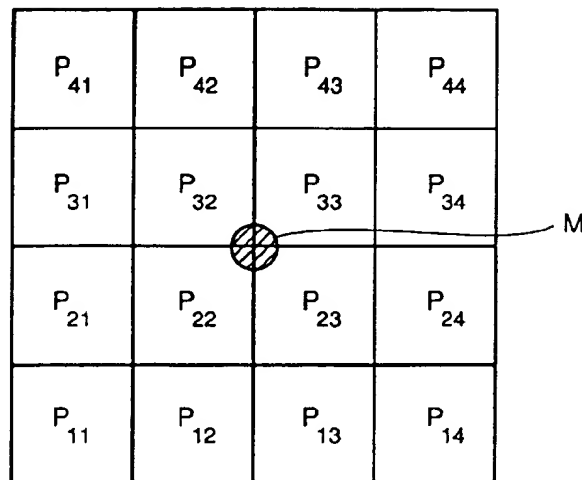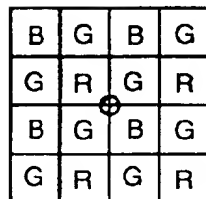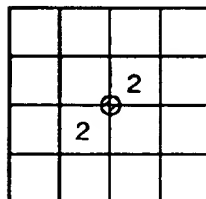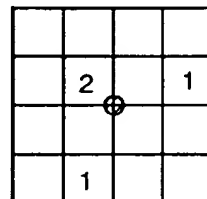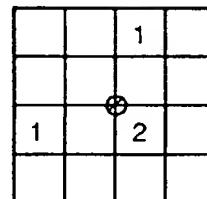
WEGHT
COEFFICIENT
FOR B SIGNAL

FIG. 11A   FIG. 11B   FIG. 11C   FIG. 11D

ARRANGEMENT
2

WEGHT
COEFFICIENT
FOR G SIGNAL
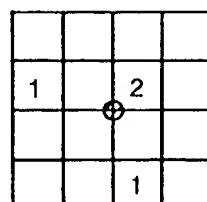
WEGHT
COEFFICIENT
FOR R SIGNAL
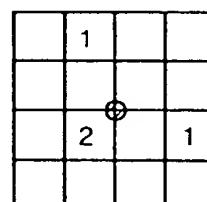
WEGHT
COEFFICIENT
FOR B SIGNAL

FIG. 12A

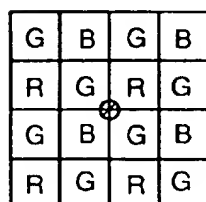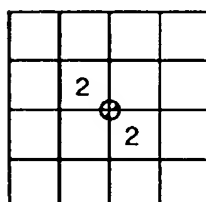| G	R	G	R
B	G	B	G
G	R	G	R
B	G	B	G

ARRANGEMENT 3

FIG. 12B

WEGHT COEFFICIENT FOR G SIGNAL

FIG. 12C

WEGHT COEFFICIENT FOR R SIGNAL

FIG. 12D

WEIGHT COEFFICIENT FOR B SIGNAL

FIG. 13A

R	G	R	G
G	B	G	B
R	G	R	G
G	B	G	B

ARRANGEMENT 4

FIG. 13B

WEGHT COEFFICIENT FOR G SIGNAL

FIG. 13C

WEGHT COEFFICIENT FOR R SIGNAL

FIG. 13D

WEGHT COEFFICIENT FOR B SIGNAL

FIG. 14
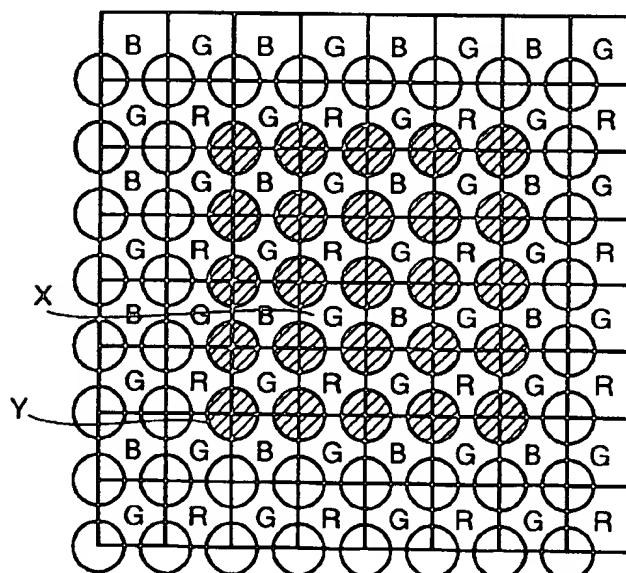
FIG. 15
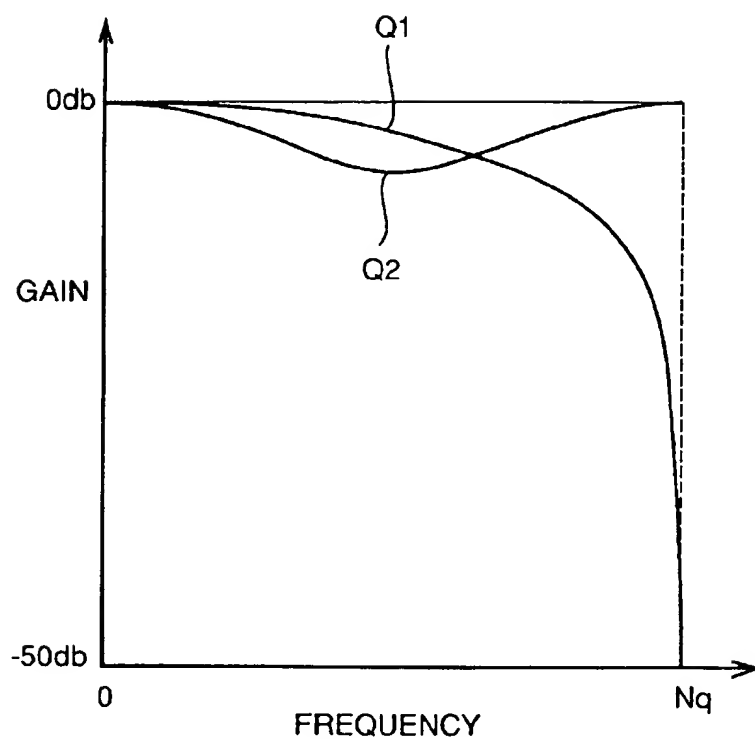
FIG. 16

ARRANGE-MENT / SELECTOR	ARRANGE-MENT 1	ARRANGE-MENT 2	ARRANGE-MENT 3	ARRANGE-MENT 4
SELECTOR 24	b	a	a	b
SELECTOR 25	b	a	a	b
SELECTOR 26	a	b	b	a
SELECTOR 27	a	b	b	a
SELECTOR 28	b	a	a	b
SELECTOR 29	a	b	b	a
SELECTOR 30	a	b	b	a
SELECTOR 31	b	a	a	b
SELECTOR 32	b	b	a	a
SELECTOR 33	b	b	a	a
SELECTOR 34	a	a	b	b
SELECTOR 35	a	a	b	b
SELECTOR 36	a	a	b	b
SELECTOR 37	b	b	a	a

1-CHIP COLOR VIDEO CAMERA FOR GENERATING INTER-PIXEL COLOR SIGNAL COMPONENT BY INTERPOLATING PRIMARY COLOR SIGNALS FROM NEIGHBORING PIXELS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a color video camera. More specifically, the present invention relates to a 1-chip color video camera having a color separation circuit for processing signals from a solid-state image sensor in which primary color filters, that is, red, green and blue (hereinafter simply referred to as R, G and B) are arranged mosaic-wise.

2. Description of the Background Art

As disclosed in the Description of the Prior Art of Japanese Patent Laying-Open No. 63-97078 (H04N9/N7), a color video camera using 1-chip for primary colors includes a solid-state image sensor having a photoreceptor portion, a charge transfer portion and a transfer control portion.

On the photoreceptor portion, a mosaic microfilter is deposited.

More specifically, referring to FIG. 1, the photoreceptor portion 85 of solid-state image sensor 1 includes a plurality of photoelectric converting elements arranged in a matrix, and mosaic elements of the microfilter are correspondingly arranged for respective photoelectric converting elements. Namely, a microfilter corresponding to one color, for example, one of R, G and B is allotted to one photoelectric converting element. There are various combinations of filter arrangement of R, G and B in such a mosaic microfilter. One typical example has a combination in which odd numbered rows viewed from below includes GRGR . . . , and even numbered rows include GBGB . . . , as shown in FIG. 2. More specifically, filters corresponding to green, which requires high resolution, are arranged in black squares of a checker board, and R and B filters are arranged on white squares (hereinafter, referred to as checkerwise arrangement). In this case, rows including R filters and rows including B filters are alternately arranged. This arrangement is generally referred to as a Bayer type arrangement.

From respective pixels of the solid-state image sensor on which the microfilter is arranged as described above, color signals corresponding to the colors of associated color filters are output. The color signals are separated into R, G and B color signals respectively, by a color separation circuit in a succeeding stage.

FIG. 1 is a schematic block diagram showing a structure of the solid-state image sensor, that is, a charge coupled device (hereinafter referred to as CCD) 1.

CCD-1- includes a photoreceptor portion 85 having a plurality of photoelectric converting elements, for example, photodiodes, arranged in a matrix corresponding to respective pixels; a plurality of vertical transfer registers 83 receiving charges stored in the diodes corresponding to the incident light for transferring charges successively in vertical direction; a vertical driving circuit 81 for outputting a clock pulse voltage for controlling the operation of vertical transfer registers 83; a horizontal transfer register 84 for receiving charges transferred by respective vertical charge transfer registers for horizontally transferring and outputting signals by converting the successively transferred signal charges to a voltage; and a horizontal driving circuit 82 for generating a clock voltage for controlling the operation of the horizontal transfer register 84.

In other words, solid-state image sensor 1 has a structure of a so-called interline transfer CCD.

Therefore, in each pixel at photoreceptor portion 85, light intensity of incident light received through the corresponding microfilter is converted to an electrical signal, and output as a corresponding analog signal, row by row of pixels.

When the mosaic microfilter such as described above is used, only an R signal is obtained from the pixel on which an R filter is disposed, and G and B signals cannot be obtained. Therefore, the G and B signals of this pixel must be generated by interpolation from G and B signals of neighboring pixels.

In a so-called digital camera in which signals from a solid-state image sensor are digitized for further processing, interpolation of a missing signal has been performed by the following operation.

More specifically, in accordance with the arrangement of color filters, a two-dimensional missing signal interpolating digital filter performs weighting, using a weight coefficient predetermined for each pixel. More specifically, signals, of the same color as the missing signal, obtained from adjacent neighboring signals are multiplied by respective weight coefficients, and resulting multiplied values are added and then divided by a sum of all weight coefficients, that is, a so-called weighted means is calculated, so as to obtain a color signal which is of the same color as the missing signal.

FIG. 2 shows a pattern of arrangement of R, G and B of the mosaic microfilter of CCD 1-shown in FIG. 1. In the pattern shown in FIG. 2, there are four possible arrangements, that is, H1, H2, H3 and H4 shown in FIGS. 3A, 4A, 5A and 6A, respectively of color filters for a block of three pixels by three pixels with an arbitrary pixel positioned at the center.

FIG. 3A shows one (hereinafter referred to as arrangement H1) of four arrangements, in which a G filter is deposited on the central pixel. In this case, the G signal obtained from this pixel is multiplied by the weight coefficient of "4" as shown in FIG. 3B, and then it is divided by "4", so that the G signal is used as it is, as the G signal of the central pixel. As for the R signal, R signals obtained from upper and lower adjacent pixels on which R filters are deposited are multiplied by the weight coefficient of "2" respectively, as shown in FIG. 3C, and the value obtained by adding the R signals of the upper and lower pixels is divided by "4", whereby the R signal of the central pixel is generated. Further, as for the B signal, B signals obtained from left and right adjacent pixels on which B filters are arranged are multiplied by the weight coefficient of "2", respectively, as shown in FIG. 3D, and the value obtained by adding the B signals of the left and right pixels is divided by "4", whereby the B signal for the central pixel is generated.

FIG. 4(A) shows another (referred to as arrangement H2) of the four arrangements, in which a B filter is deposited on the central pixel. Therefore, as for the G signal, G signals obtained from upper, lower, left and right four pixels are multiplied by the weight coefficient of "1" as shown in FIG. 4B, and the value obtained by adding the G signals from these four pixels is divided by "4". Thus the G signal for the central pixel is generated. As for the R signal, R signals obtained from upper left, upper right, lower left and lower right four pixels are multiplied by the weight coefficient of "1", respectively, as shown in FIG. 4C, and the value obtained by adding the R signals from these four pixels is divided by "4", whereby the R signal for the central pixel is generated. As for the B signal, since a B filter is disposed on the central pixel, the B signal obtained from this pixel is

multiplied by the weight coefficient of "4" as shown in FIG. 4D, and the resulting value is divided by "4", so that the B signal is used, as it is, as the B signal of the central pixel.

FIG. 5A shows a still another one (referred to as arrangement H3) of the four arrangements, in which an R filter is disposed on the central pixel. Therefore, as for the G signal, G signals obtained from upper, lower, left and right four pixels are multiplied by the weight coefficient of "1" as shown in FIG. 5B, and the value obtained by adding the G signals from these four pixels is divided by "4", whereby G signal of the central pixel is generated. As for the R signal, since an R filter is disposed on the central pixel, the R signal obtained from this pixel is multiplied by the weight coefficient of "4" as shown in FIG. 5C, and the resulting value is divided by "4". Thus the R signal is used, as it is, as the R signal for the central pixel. As for the B signal, B signals obtained from upper left, upper right, lower left and lower right four pixels are multiplied by the weight coefficient of "1", respectively, as shown in FIG. 5D, and the value obtained by adding the B signals from these four pixels is divided by "4", whereby the B signal for the central pixel is generated.

FIG. 6A shows still another one (referred to as arrangement H4) of the four arrangements, in which a G filter is disposed on the central pixel. As shown in FIG. 6B, the G signal obtained from the central pixel is multiplied by the weight coefficient of "4", and the resulting value is divided by "4", so that the G signal, as it is, is used as the G signal for the central pixel. As for the R signal, R signals obtained from left and right adjacent pixels on which R filters are disposed are multiplied by the weight coefficient of "2", respectively, as shown in FIG. 6C, and the value obtained by adding these R signals of the left and right pixels is divided by 4, whereby the R signal for the central pixel is generated. As for the B signal, B signals obtained from upper and lower adjacent pixels on which B filters are disposed are multiplied by the weight coefficient of "2" , respectively, as shown in FIG. 6D, and the value obtained by adding the B signals of the upper and lower pixels is divided by "4", whereby the B signal for the central pixel is generated.

Such interpolation of color signals as described above is performed by means of an interpolation digital filter consisting of a two-dimensional FIR filter (Finite Impulse Response) filter.

The transfer function H (Z) of the FIR filter with respect to the aforementioned weight coefficients are as follows.

[ARRANGEMENT H1]

(HORIZONTAL & VERTICAL DIRECTIONS OF G SIGNAL)

$H (z) = \Sigma hmz^{-m} = 1$

(HORIZONTAL DIRECTION OF R SIGNAL)

$H (z) = 1$

(VERTICAL DIRECTION OF R SIGNAL)

$H (z) = \Sigma hmz^{-m} = 1 \times z^{-0} + 0 \times z^{-1} + 1 \times z^{-2} = 1 + z^{-2}$

(HORIZONTAL DIRECTION OF B SIGNAL)

$H (z) = 1 + z^{-2}$

(VERTICAL DIRECTION OF B SIGNAL)

$Z (z) = 1$

[ARRANGEMENT H2]

(HORIZONTAL & VERTICAL DIRECTIONS OF G SIGNAL)

$H (z) = \Sigma hmz^{-m} = 1 \times z^{-0} + 2 \times z^{-1} + 1 \times z^{-2} = 1 + 2z^{-1} + z^{-2}$

(HORIZONTAL & VERTICAL DIRECTIONS OF R SIGNAL) $H (z) = \Sigma hmz^{-m} = 1 \times z^{-0} + 0 \times z^{1} + 1 \times z^{-2} = 1 + z^{-2}$

(HORIZONTAL & VERTICAL DIRECTIONS OF B SIGNAL) $H (z) = 1$

[ARRANGEMENT H3]

(HORIZONTAL & VERTICAL DIRECTIONS OF G SIGNAL)

$H (z) = \Sigma hmz^{-m} = 1 \times z^{-0} + 2 \times z^{-1} 1 \times z^{-2} = 1 + 2z^{-1} + z^{-2}$

(HORIZONTAL & VERTICAL DIRECTIONS OF R SIGNAL) $H (z) = 1$

(HORIZONTAL & VERTICAL DIRECTIONS OF B SIGNAL) $H (z) = 1 + z^{-2}$

[ARRANGEMENT H4]

(HORIZONTAL & VERTICAL DIRECTIONS OF G SIGNAL) $H (z) = 1$

(HORIZONTAL DIRECTION OF R SIGNAL)

$H (z) = 1 + z^{-2}$

(VERTICAL DIRECTION OF R SIGNAL)

$H (z) = 1$

(HORIZONTAL DIRECTION OF B SIGNAL)

$H (z) = 1$

(VERTICAL DIRECTION OF B SIGNAL)

$H (z) = 1 + z^{-2}$

FIG. 7 is a graph showing characteristics of the interpolation filter as represented by the transfer functions above, in which the ordinate indicates gain of the interpolation filter, while the abscissa represents operational frequency of the interpolation filter. More specifically, for the image pick up signal sampled at a prescribed sampling time, the frequency plotted on the abscissa corresponds to a reciprocal of the period of spatial change in the picked-up image.

The characteristics of the interpolation filter as represented by the transfer functions above for each of the R, G and B color signals correspond to the curve P1, P2 and P3 shown in FIG. 7 with respect to the horizontal and vertical directions.

As for the arrangement H1 shown in FIG. 3A, the G signal can be obtained from the pixel which is at the center both in the horizontal and vertical directions, and hence there is not the necessity of interpolation. Therefore, the characteristic is as represented by the curve P1, which is not dependent on frequency.

As for the R signal, the characteristic is as represented by the curve P1 in the horizontal direction, since interpolation from left and right pixels is not necessary. However, in the vertical direction, it is interpolated by using R signals of upper and lower adjacent pixels. Therefore, the characteristic is as shown by the curve P3 which lowers toward one half (hereinafter referred to as ½ Nyquist frequency) of Nyquist frequency Nq, which is the sampling frequency, and has an alias component in the frequency range higher than ½ Nyquist frequency.

Further, the B signal has the characteristic as represented by the curve P3 in the horizontal direction as it is interpolated by B signals from left and right pixels, and in vertical direction, the characteristic is as represented by the curve P1, since it is not interpolated from upper and lower adjacent pixels.

As for the arrangement H2 of FIG. 4A, the G signal in the horizontal direction has the characteristic as represented by the curve P2 in which gain of high frequency component lowers because of the characteristic of a two-dimensional FIR filter as the G signals of left and right adjacent pixels as well as upper and lower adjacent pixels contribute to interpolation. It has the characteristic as represented by the curve P2 also in the vertical direction, since G signals from upper and lower adjacent pixels as well as left and right adjacent pixels contribute to interpolation.

As for the R signal, there are no pixels contributing to interpolation in the central column, and hence in horizontal

direction, it cannot help but depend on the left and right columns. Therefore, the characteristic is as shown by the curve P3. Similarly, in vertical direction, there is not a pixel contributing to interpolation in the central row, and hence it cannot help but depend on upper and lower rows. Therefore, it also has the characteristic as represented by the curve P3.

The B signal does not require interpolation, and hence it has the characteristic as represented by the curve P1 both in the horizontal and vertical directions.

The arrangement H3 shown in FIG. 5A will be described. As in arrangement H2, the G signal has the characteristic as represented by the curve P2 both in the horizontal and vertical directions.

The R signal, which needs no interpolation, has the characteristic as represented by the curve P1 both in the horizontal and vertical directions.

As for the B signal, it has the characteristic as represented by the curve P3 both in the horizontal and vertical directions, as does the R signal of arrangement H2.

The arrangement H4 shown in FIG. 6A will be described. The G signal, which needs no interpolation, has the characteristic as represented by the curve P1 both in the horizontal and vertical directions.

The R signal has the characteristic as represented by the curve P3 in the horizontal direction, and has the characteristic as represented by the curve P1 in the vertical direction, as does the B signal in arrangement H1.

Further, the B signal has the characteristic as represented by the curve P1 in the horizontal direction, and the characteristic as represented by the curve P3 in the vertical direction, as does the R signal of arrangement H1.

In this manner, in the conventional interpolation filter, R, G and B signals have filter characteristics different from each other in accordance with the arrangement of the color filters. If the gain of the interpolation filter at ½ Nyquist frequency much differs from the gain near the Nyquist frequency Nq in FIG. 7, there would be significant color moire near such frequencies.

In order to suppress such color moire in the 1-chip color video camera, an optical lowpass filter (LPF) is placed in an optical path of incident light to CCD 1. The optical lowpass filter removes high frequency component before sampling by the CCD 1, so as to reduce the alias component at the sampling, and hence color moire can be suppressed. However, that the high frequency component of the incident light that is removed induces, at the same time, lower resolution.

Further, dependent on the arrangement, the G signal, which among primaries, contributes most to brightness would have such a characteristic as represented by the curve P2 which suffers from significant attenuation in the high frequency range, which results in degraded resolution.

As for of color filters themselves, the color filter of three primaries such as described above but color filters of complementary colors may be used in lieu of the color filers of three primary colors such as described above. However, in view of color reproduction property, generally primary color filters are superior to complementary color filters. Therefore, a method in which color signals are interpolated by using color filters of primary colors, rather than complementary colors, is desirable.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a 1-chip color video camera that provides a frequency characteristic that exhibits relatively little attenuation of gain up to a high frequency range, for the G signal which contributes, of three primary colors, most to brightness.

Another object of the present invention is to provide a 1-chip color video camera capable of minimizing difference between frequency characteristics of R and B signals and the frequency characteristic of the G signal.

A still further object of the present invention is to provide a 1-chip color video camera in which primary colors the same frequency characteristics for every pixel of the solid-state image sensor.

In summary, the present invention provides a 1-chip color video camera including a solid-state image sensor and an interpolating circuit.

The solid-state image sensor includes photoelectric converting elements, corresponding to respective pixels, arranged in an array. The solid-state image sensor includes a color filter array in which primary color filters are disposed in a prescribed arrangement, corresponding to the photoelectric converting elements, on a photoreceptor surface side. The interpolating circuit receives an output from the solid-state image sensor and outputs a corresponding color signal. The circuit includes a parallel color signal output circuit, a control circuit, and a color separation circuit. The parallel color signal output circuit receives output from the solid-state image sensor and successively outputs a color signal corresponding to a prescribed even number of rows of pixels column by column in parallel and in synchronization. The control circuit outputs a synchronized interpolation designating signal in accordance with correspondence between the color signals output column by column from the parallel color signal output circuit and the arrangement of predetermined weight coefficients for the prescribed arrangement of the color filter array. The color separation circuit receives outputs from the parallel color signal output circuit and, in accordance with the interpolation designating signal, performs interpolation of color signals from a pixel block including prescribed even numbered rows and prescribed even numbered columns of pixels, and outputs successively and, in synchronization, a color signal corresponding to the central position of the pixel block.

In accordance with another aspect, the 1-chip color video camera includes a solid-state image sensor and an interpolating circuit.

The solid-state image sensor includes photoelectric converting elements corresponding to respective pixels, arranged in an array. The solid-state image sensor includes a color filter array in which primary color filters are arranged mosaic-wise corresponding to the photoelectric converting elements, on a photoreceptor surface side. The color filter array includes, in a color filter arrangement of arbitrary two rows by two columns, green filters arranged in diagonal direction. The interpolating circuit receives an output from the solid-state image sensor and interpolates a green signal component at the central portion of a pixel block corresponding to the arbitrary color filter arrangement of two rows by two columns, by mean value of green signals obtained from photoelectric converting elements corresponding to the green filters arranged in the diagonal direction.

According to a still further aspect of the present invention, the 1-chip color video camera includes a solid-state image sensor and an interpolating circuit. The solid-state image sensor includes photoelectric converting elements, corresponding to respective pixels, arranged in an array. The solid-state image sensor includes a color filter array in which primary color filters are arranged mosaic-wise corresponding to the photoelectric converting elements, on a photoreceptor surface side. The color filter array includes red and

blue filters arranged checkerwise, and rows including red filters and rows including blue filters are alternately arranged. The interpolation circuit interpolates each of red and blue color signal components at the central portion of a pixel block, based on the signals from the pixel block including 4 rows by 4 columns of pixels, that is, 16 pixels. The. interpolating circuit includes a two-dimensional non-recursive digital filter circuit for switching column-wise values of vertical sums of weight coefficients between (0, 3, 0, 1) and (1, 0, 3, 0), in accordance with the arrangement of color filters corresponding to the sixteen pixels.

According to a still further aspect of the present invention, the 1-chip color video camera includes a solid-state image sensor and an interpolating circuit.

The solid-state image sensor includes a color filter array in which primary color filters are arranged mosaic-wise corresponding to photoelectric converting elements on a photoreceptor surface side. The interpolating circuit generates a plurality of color signal components at a position shifted by half a pixel in horizontal and vertical directions from the center of an arbitrary pixel, based on color signal component of a plurality of neighboring pixels.

Therefore, an advantage of the present invention is that the G signal, which contributes most to brightness, exhibits a frequency characteristic that suffers relatively little attenuation up to the high frequency range; hence high resolution becomes possible.

Another advantage of the present invention is that generation of a color false signal is suppressed, since difference between the frequency characteristics of R and B signals and that of G signal is small at ½ Nyquist frequency.

A still another advantage of the present invention is that same frequency characteristics can be provided for every pixel with respect to each of the three primary colors.

The foregoing and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic block diagram showing a structure of a conventional CCD 1.

FIG. 2 is a schematic diagram showing a structure of a mosaic filter disposed on a conventional CCD 1.

FIGS. 3A to 3D are illustrations showing allotment of weight coefficients for interpolation in a conventional color video camera, in which FIG. 3A shows filter arrangement H1, FIG. 3B shows an arrangement of weight coefficients for the G signal, FIG. 3C shows an arrangement of weight coefficients for the R signal and FIG. 3D shows an arrangement of weight coefficients for the B signal.

FIGS. 4A to 4D are illustrations showing allotment of weight coefficients for interpolation in a conventional color video camera, in which FIG. 4A shows filter arrangement H2, FIG. 4B shows an arrangement of weight coefficients for the G signal, FIG. 4C shows an arrangement of weight coefficients for the R signal and FIG. 4D shows an arrangement of weight coefficients for the B signal.

FIGS. 5A to 5D are illustrations showing allotment of weight coefficients for interpolation in a conventional color video camera, in which FIG. 5A shows filter arrangement H3, FIG. 5B shows an arrangement of weight coefficients for the G signal, FIG. 5C shows an arrangement of weight coefficients for the R signal and FIG. 5D shows an arrangement of weight coefficients for the B signal.

FIGS. 6A to 6D are illustrations showing allotment of weight coefficients for interpolation in a conventional color video camera, in which FIG. 6A shows filter arrangement H4, FIG. 6B shows an arrangement of weight coefficients for the G signal, FIG. 6C shows an arrangement of weight coefficients for the R signal and FIG. 6D shows an arrangement of weight coefficients for the B signal.

FIG. 7 is a graph showing frequency characteristics of three primary signals after interpolation in the conventional color video camera.

FIG. 8 is a block diagram showing a structure of a color signal processing circuit 100 in accordance with one embodiment of the present invention.

FIG. 9 shows a position of interpolation portion in a pixel block in accordance with one embodiment of the present invention.

FIGS. 10A to 10D are illustrations showing allotment of weight coefficients for arrangement 1 for interpolation in accordance with one embodiment of the present invention in which FIG. 10A shows filter arrangement, FIG. 10B shows arrangement of weight coefficients for the G signal, FIG. 10C shows arrangement of weight coefficients for the R signal, and FIG. 10D shows arrangement of weight coefficients for the B signal.

FIGS. 11A to 11D are illustrations showing allotment of weight coefficients for arrangement 2 for interpolation in accordance with one embodiment of the present invention in which FIG. 11A shows filter arrangement, FIG. 11B shows arrangement of weight coefficients for the G signal, FIG. 11C shows arrangement of weight coefficients for the R signal, and FIG. 11D shows arrangement of weight coefficients for the B signal.

FIGS. 12A to 12D are illustrations showing allotment of weight coefficients for arrangement 3 for interpolation in accordance with one embodiment of the present invention in which FIG. 12A shows filter arrangement, FIG. 12B shows arrangement of weight coefficients for the G signal, FIG. 12C shows arrangement of weight coefficients for the R signal, and FIG. 12D shows arrangement of weight coefficients for the B signal.

FIGS. 13A to 13D are illustrations showing allotment of weight coefficients for arrangement 4 for interpolation in accordance with one embodiment of the present invention in which FIG. 13A shows filter arrangement, FIG. 13B shows arrangement of weight coefficients for the G signal, FIG. 13C shows arrangement of weight coefficients for the R signal, and FIG. 13D shows arrangement of weight coefficients for the B signal.

FIG. 14 shows position of interpolation portion on the CCD in accordance with one embodiment of the present invention.

FIG. 15 shows frequency characteristics of three primary signals in accordance with one embodiment of the present invention.

FIG. 16 shows switching control of a selector circuit in a color signal processing circuit 100 in accordance with one embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 8 is a block diagram showing a structure of a color signal processing circuit 100 including components from a CCD 1 as an image sensor up to a color separation circuit 8, in a color video cameral in accordance with one embodiment of the present invention.

The incident light is formed on CCD 1 by means of a lens (not shown), and photo-electrically converted to an image signal. A microfilter 70 including R, G and B color filters arranged mosaic-wise is provided on the photoreceptor surface of CCD 1. It is assumed that the arrangement of respective color filters of mosaic microfilter 70 is the same as the prior art example shown in FIG. 2. The light which has passed through the lens is supplied through microfilter 70 to photoreceptor portion of CCD-1. In accordance with the intensity of incident light received through the filter, charges stored in photoreceptor portion 85 (see FIG. 1) for one field period are transferred by vertical transfer register 83 and horizontal transfer register 84 to be output externally from CCD 1.

More specifically, CCD 1 includes photoreceptor portion 85; vertical transfer register 83 for vertically transferring an output in accordance with the light intensity received at photoreceptor portion 85; horizontal transfer register 84 arranged at a terminating end of the vertical transfer register for transferring charges transferred from the vertical transfer register in a horizontal direction; a vertical driving circuit 81 for receiving a vertical synchronizing signal, a horizontal synchronizing signal and a clock signal of a fixed frequency for outputting a vertical transfer pulse to cause vertical transfer register 83 to execute charge transfer; and a horizontal driving circuit 82 for receiving similar signals as vertical driving circuit 81 for outputting a horizontal transfer pulse for driving charge transfer by horizontal transfer register 84. In synchronization with the vertical synchronizing signal, an output corresponding to the light intensity received at photoreceptor portion 85 is read to vertical transfer register 83, and in the period of the horizontal synchronizing signal, charges are transferred vertically row by row in vertical transfer register 83. In accordance with the clock signal period, charges are transferred column by column in a horizontal direction in horizontal transfer register 84.

Such driving operation of the CCD 1 as described above is a well known operation for a so-called interline type CCD 1. The vertical and horizontal synchronizing signals as well as the clock signal are output from a timing pulse generating circuit 71 shown in FIG. 8.

Again referring to FIG. 8, the image signal output from CCD 1 is subjected to known noise removal operation in a correlated double sampling circuit (hereinafter referred to as CDS circuit) 2, amplified by an auto gain control circuit (hereinafter referred to as AGC circuit) 3, and converted to a digital signal in an A/D converter 4.

The digital image signal is applied as a first input signal directly to a color separation circuit 8, which is a two-dimensional non-recursive digital filter, as well as to a scan line delay provider (hereinafter referred to as 1H delay provider) 5. An output from 1H delay provider 5 is input as a second input signal to color separation circuit 8 as well as to a 1H delay provider 6 of a succeeding stage. Further, an output from 1H delay provider 6 is input as a third input signal to color separation circuit 8 as well as to a 1H delay provider 7 of a succeeding stage, and an output from 1H delay provider 7 is input, as a fourth input signal, to color separation circuit 8.

Therefore, the first to fourth four input signals correspond to image signals of four scanning lines (four lines), and the signals from the four lines are collectively input to color separation circuit 8.

Thus, an FIR (Finite Impulse Response) filter is implemented by color separation circuit 8 and three 1H delay providers 5, 6 and 7.

Color separation circuit 8 includes ten 1 clock delay providers 10, 11, 12, 13, 14, 15, 16, 17, 18, and 19 for providing a delay of 1 clock for the input signal; four multipliers 20, 21, 22, and 23 for multiplying the value of an input signal by 2; fourteen selectors 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36 and 37 for selecting one of two input signals; and five adders 38, 39, 40, 41 and 42 for adding two input signals.

The structure will be more specifically described. The first input signal from A/D converter 4 is input to 1 clock delay provider 10, and the output from delay provider 10 is directly input to terminal 24b of selector 24 as well as to 1 clock delay provider 14. The output from 1 clock delay provider 14 is input to a terminal 24a of selector 24.

The second input signal which is an output signal from 1H delay provider 5 is directly input to a terminal 25b of selector 25, as well as to 1 clock delay provider 11. The output from 1 clock delay provider 11 is input to 1 clock delay provider 15 of the succeeding stage, as well as to multiplier 20. The output from 1 clock delay provider 15 is input to 1 clock delay provider 18 of the succeeding stage, as well as to multiplier 21. The output from 1 clock delay provider 18 is input to terminal 25a of selector 25.

The third input signal, which is the output from 1H delay provider 6 is directly input to terminal 26b of selector 26, as well as to 1 clock delay provider 12. The output from 1 clock delay provider 12 is input to 1 clock delay provider 16 of the succeeding stage as well as to multiplier 22. The output from 1 clock delay provider 16 is input to 1 clock delay provider 19 of the succeeding stage, as well as to multiplier 23. The output from 1 clock delay provider 19 is input to a terminal 26a of selector 26.

The fourth input signal, which is the output from 1H delay provider 7 is input to 1 clock delay provider 13. The output from delay provider 13 is directly input to a terminal 27b of selector 27 as well as to 1 clock delay provider 17. The output from 1 clock delay provider 17 is input to a terminal 27a of selector 27.

The output from selector 24 is input to terminals 32a and 34a of selectors 32 and 34, respectively, of the succeeding stage. The output from selector 25 is input to terminals 32b and 34b of selectors 32 and 34, respectively. The output from selector 26 is input to terminals 33a and 35a of selectors 33 and 35, respectively of the succeeding stage. The output from selector 27 is input to terminals 33b and 35b of selectors 33 and 35, respectively.

The output from multiplier 20 is input to terminals 28a and 30a of selectors 28 and 30, respectively, of the succeeding stage. The output from multiplier 21 is input to terminals 28b and 31a of selectors 28 and 31, respectively, of the succeeding stage. The output from multiplier 22 is input to terminals 29a and 30b of selectors 29 and 30, respectively, of the succeeding stage. The output from multiplier 23 is input to terminals 29b and 31b of selectors 29 and 31, respectively, of the succeeding stage.

The outputs from selectors 32 and 33 are added in adder 38 of the succeeding stage, and outputs from selectors 34 and 35 are added in adder 39 of the succeeding stage. The output from selector 28 is input to terminals 36a and 37a of selectors 36 and 37, respectively, of the succeeding stage. The output from selector 29 is input to terminals 36b and 37b of selectors 36 and 37, respectively, of the succeeding stage. The outputs from selectors 30 and 31 are added in adder 40.

The output from adder 38 is input, together with the output from selector 36, to adder 41, and added therein. The

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output from adder 39 is input, together with the output from selector 37, to adder 42, and added therein.

The output from adder 41 would finally be the R signal which has gone through color separation processing; the output from adder 42 would be the B signal, and the output from adder 40 would be the G signal.

In the above described flow of signal processing, it becomes possible to process signals of four successive pixels of a corresponding line, as three 1 clock delay providers are arranged in series for each input signal. Signals of a 4×4 pixel block can be handled if three 1 block delay providers are connected in series for each input signal. Switching of fourteen selectors is controlled in the following manner by a switch control signal from switch control circuit 72.

Assume that a 4×4 pixel block of CCD 1 includes 16 pixels represented by P11 to P44 as shown in FIG. 9, for example. Color separation circuit 8 generates R, G and B signals at the central portion M denoted by a hatched circle of the shown in FIG. 9 by interpolation of R, G and B signals from sixteen neighboring pixels.

More specifically, color separation circuit 8 generates R, G and B signals at a position obtained by shifting four central pixels of the 4×4 pixel block by half a pixel in horizontal and vertical directions, in other words, the position obtained by offsetting the four central pixels by half a pixel in horizontal and vertical directions, by using R, G and B signals from some of the neighboring sixteen pixels.

Consider sixteen pixels shown in FIG. 9. First, signals from lowermost one line of pixels are successively output from horizontal transfer register 84 of CCD 1 at every 1 clock, namely, P11 - → P12 - → P13 - → P14. When output of the signals of all the pixels in this line is completed, signals from pixels of the second lowest line are output, namely, P21 - → P22 - → P23 - → P24.

Thereafter, signals from the third from the bottom line are output, namely, P31 - → P32 - → P33 - → P34.

When the output of signals from the pixels of the third line from the bottom is completed, signals from respective pixels in the uppermost line are successively output, namely, P41 - →P42 - → P43 - → P44.

For convenience of description, in the following, the signal obtained by photoelectric conversion from pixel P11 will be denoted by S11, the signal from pixel P12 will be denoted by S12 and similarly, signals output from pixels up to P44 will be denoted by the reference characters up to S44.

The image signals S11 to S44 are passed through CDS circuit 2 and AGC circuit 3 and successively converted to digital values by A/D converter 4.

By the time the output of four lines is completed and the signal S44 from pixel P44 is output from A/D converter 4, one line of signals, that is image signals S11 to S14 are input to color separation circuit 8 from 1H delay provider 7, and one line of signals, that is, image signals S21 to S24 are input to color separation circuit 8 from 1H delay provider 6. Similarly, one line of signals, that is, image signals S31 to S34 are input to color separation circuit 8 from 1H delay provider 5, and one line of signals, that is, image signals S41 to S44 are directly input to color separation circuit 8.

Therefore, signal S12 is output from 1 clock delay provider 17, signal S13 is output from 1 clock delay provider 13, and signal S14 is output from 1H delay provider 7. Similarly, signals S21, S22 and S23 are output from 1 clock delay providers 19, 16 and 12, respectively, and signal S24 is output from 1H delay provider 6. Signals S31, S32 and

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S33 are output from 1 clock delay providers 18, 15 and 11, respectively, and signal S34 is output from 1H delay provider 5. Signals S42 and S43 are output from 1 clock delay providers 14 and 10, respectively, and signal S44 is output from A/D converter 4.

In the structure of color separation circuit 8 described above, in order to perform interpolation in color separation circuit 8, a pixel block consisting of 16 pixels, that is, 4×4, on CCD 1 must be set. FIG. 14 shows positions where interpolation takes place with respect to the arrangement of the mosaic color filter shown in FIG. 2. As already described, 4×4, that is, 16 pixels are necessary for interpolation. Therefore, as shown in FIG. 14, the result of interpolation when the image signals from pixels of lowermost three rows are output is meaningless. Further, interpolation at the time of output of first three pixels of the fourth row from the bottom is similarly meaningless. More specifically, the result of interpolation at interpolation portion Y comes to have meaning for the first time when the image signal of pixel X is obtained, in FIG. 14.

Therefore, switching control of respective selectors for interpolation must be started from the time point when image signal from pixel X is output from CCD 1.

Here, there are four possible arrangements as shown in FIGS. 10 to 13 of 4×4=16 pixels for the microcolor filters shown in FIG. 14.

FIGS. 10A to 13A show arrangements of color filter arrays of 4×4=16 pixels. Figs. 10B to 13B show weight coefficients for respective pixels when the G signal at the central point is to be generated by interpolation. FIGS. 10C to 13C show weight coefficients for respective pixels when the R signal at the central position is to be generated by interpolation. FIGS. 10D to 13D show weight coefficients for respective pixels when the B signal at the central position is to be generated by interpolation.

Referring to FIG. 14, in the process of interpolation at interpolation portion Y performed as a G signal is read from pixel X, 16 pixels surrounding interpolation portion Y at the center would be as shown in FIG. 10A. Therefore, for the interpolation of interpolation portion Y, switching control appropriate for arrangement 1 of respective selector circuits becomes necessary.

When B signal is read from a pixel next to the pixel X in the right, interpolation at an interpolation portion adjacent to interpolation portion Y on the right becomes possible. The arrangement of sixteen pixels surrounding this interpolation portion corresponds to arrangement 2 and hence switch control appropriate for arrangement 2 of respective selector circuits becomes necessary.

Thereafter, as long as image signals are output from the pixels of this line, arrangement of sixteen pixels surrounding each interpolation portion would be arrangements 1 and 2 switched alternately. Therefore, relative to this switching, selectors must be controlled to be switched to the state suitable for the respective arrangements.

As for the next line, that is, a line above the line to which pixel S belongs, at a time point when R signal is read from the fourth from the left pixel, interpolation at an interpolation portion adjacent to interpolation portion Y on the line above becomes possible. The arrangement of sixteen pixels surrounding this interpolation portion corresponds to arrangement 3 shown in FIG. 12A. Therefore, selector circuits must be switched to be suitable for arrangement 3. Further, when reading of the G signal from the adjacent right pixel is completed, interpolation at interpolation portion adjacent to interpolation portion Y on upper right-position

becomes possible. The arrangement of sixteen pixels surrounding this interpolation portion corresponds to arrangement 4 shown in FIG. 13A. Therefore, selector circuits must be switched to be suitable for arrangement 4.

Thereafter, while the image signals are output from the pixels of this line, the arrangement of sixteen pixels surrounding the corresponding interpolation portions correspond to arrangements 3 and 4 switched alternately. Therefore, selector circuits must be controlled to be switched to suitable states for respective arrangements, correspondingly.

In the next row, after the point in time at which the image signal from the fourth pixel is input, switching control suitable for arrangements 1 and 2 is executed. Similarly, in the next row, after the point in time at which the image signal from the fourth pixel is input, switching control suitable for arrangements 3 and 4 is executed.

Thereafter, control for switching arrangements 1 and 2 alternately and arrangements 3 and 4 alternately for every other row is continued until reading of image signals from the pixels of the uppermost row is completed.

When reading of image signals of the one image plane is completed, stored charges at the photoreceptor portion are again read to the vertical register and reading from the lowermost line of pixels is again performed, similar switching control as described above is repeated.

In order to control switching of respective selectors as described above, actually, it is necessary to determine the position of the pixel on the CCD 1 from which image signal is being output, by means of a vertical counter and a horizontal counter included in switch control circuit 72 (see FIGS. 8 and 10A–13D).

The vertical counter is reset by the vertical synchronizing signal, counts the horizontal synchronizing signal and hence counts the line to which the pixel being processed belongs. The horizontal counter is reset by the horizontal synchronizing signal, counts the clock signals synchronized with horizontal transfer, and determines to which column in the horizontal direction the pixel being processed belongs. By these two counters, that is, vertical and horizontal counters, the position of the pixel from which an image signal is being output on the CCD 1 is determined. For example, if it is determined that the image signal from a pixel at the fourth row from the bottom and fourth column from the left is being output from CCD 1, switch control circuit 72 determines that the arrangement of 4×4=16 pixels used for interpolation corresponds to arrangement 1, and outputs a switch control signal corresponding to arrangement 1. As long as the output of pixels belonging to this line continues, switch control signals corresponding to arrangements 1 and 2 are output alternately in the period of clock signal.

If it is determined by the vertical and horizontal counters that the position on the CCD 1 of that pixel from which image signal is being output is the pixel at the fifth row from the bottom and fourth column from the left, switch control circuit 72 determines that the arrangement of 16 pixels used for interpolation corresponds to arrangement 3 and outputs a switch control signal corresponding to arrangement 3. As long as the output of image signals from pixels belonging to this line continues, switch control signals corresponding to arrangements 3 and 4 are output alternately in the period of the clock signal.

The image signal output from the corresponding pixel on the CCD 1 passes through CDS circuit 2, AGC circuit 3 and A/D converter 4, before it is input to color separation circuit 8. Therefore, after the delay of time necessary for these

processings, the switch control signal is output from switch control circuit 72 to respective selector circuits. The clock signal is in synchronization with charge transfer by horizontal transfer register 84 of CCD 1, and it also serves as a driving clock of color separation circuit 8.

FIG. 16 shows correspondence between switch control signals from switch control circuit 72 and the arrangement of sixteen pixels.

In accordance with the corresponding pixel arrangement of the image signals input to color separation circuit 8, selector circuits 24 to 37 are switched to select their corresponding inputs (a or b) as shown in FIG. 16, and interpolated R, B and G signals are output from color separation circuit 8.

The color separation operation in the color separation circuit 8 described above is as follows, with reference to FIGS. 8–13D.

First, the procedure for generating G signal will be described. When a G signal is to be generated at interpolation portion Y which is the central portion of 4×4=16 pixels at which interpolation takes place, G signals obtained from two of four pixels surrounding interpolation portion Y are used.

More specifically, in the arrangement 1 shown in FIG. 10A and in the arrangement 4 shown in FIG. 13A, G signals from pixels P22 and P33 are multiplied by the weight coefficient of "2" as shown in FIGS. 10B and 13B, and the multiplied values are added, whereby the G signal at the interpolation portion Y is generated.

In the arrangement 2 shown in FIG. 11A and in the arrangement 3 shown in FIG. 12A, G signals from pixels P32 and P23 are allotted with weight coefficient of "2" as shown in FIGS. 11B and 12B, and similar calculation is performed to generate the G signal for the interpolation portion Y.

In the above described processing, interpolation is performed by a two-dimensional two-tap filter including 1 clock delay providers 11, 12, 15, 16, multipliers 20, 21, 22, 23, selector circuits 30, 31 and adder 40 in color separation circuit 8. More specifically, for the arrangements 1 and 4, selector 30 is switched to the side of terminal 30a by the switching signal, so that the output from multiplier 20 is selected, and selector 31 is switched to that terminal 31b to select the output from multiplier 23. The signal S33 which is the output from 1 clock delay provider 11 is multiplied by 2 in multiplier 20, and input to adder 40 by selector 30. Meanwhile, the signal S22 which is the output signal from 1 clock delay provider 16 is multiplied by 2 in multiplier 23, and input by selector 31 to adder 40. In adder 40, these inputs are added, and thus G signal at interpolation portion Y is generated.

Meanwhile, for the arrangements 2 and 4, switching is controlled such that selector 30 is switched to terminal 30b to select the output from multiplier 22, and selector 31 is switched to terminal 31a to select the output from multiplier 21. The signal S23 which is the output from 1 clock delay provider 12 is multiplied by 2 in multiplier 22 and input by selector 30, to adder 40. The signal S32 which is the output signal from 1 clock delay provider 15 is multiplied by 2 in multiplier 21 and input by selector 31, to adder 40. In adder 40, these inputs are added, whereby the G signal at the interpolation portion Y is generated.

More specifically, in interpolation processing of G signal, of 4×4 pixels, only the image signals from central 2×2 pixels are used to generate the G signal.

The procedure for generating R signal will be described.

When the R signal is to be generated at interpolation portion Y, one of the four pixels surrounding interpolation portion Y and two pixels of R color filters out of the outermost 12 pixels belonging to the same row or same column as this one pixel are used, that is, R signals from the total of three pixels are used.

More specifically, for the arrangement 1, the weight coefficient of "2" is allotted to the R signal from pixel P32 as shown in FIG. 10C, and weight coefficient of "1" is allotted to the R signals from pixels P12 and P34. R signals from these three pixels are multiplied by respective weight coefficients, and the multiplied values are added to provide the R signal of the central portion Y.

Similarly, for the arrangement 2, the weight coefficient of "2" is allotted to R signal from pixel P33 as shown in FIG. 1C, and weight coefficient of "1" is allotted to the R signals from pixels P13 and P31. The R signals from these three pixels are multiplied by respective weight coefficients, and the multiplied values are added to provide the R signal of the central portion For the arrangement 3, weight coefficient of "2" is allotted to R signal from pixel P22 and weight coefficient of "1" is allotted to the R signals from pixels P24 and P42, as shown in FIG. 12C. The R signals from these three pixels are multiplied by respective weight coefficients, and the multiplied values are added to provide the R signal at the central portion Y.

For the arrangement 4, weight coefficient of "2" is allotted to the R signal of pixel P23, and weight coefficient of "1" is allotted to the R signals from pixels P21 and P43, as shown in FIG. 13C. The R signals from these three pixels are multiplied by respective weight coefficients, and the multiplied values are added to provide the R signal at the central portion Y.

In this manner, when R signal is to be calculated by weighting and adding, a two-dimensional three-tap filter including all the 1 clock delay providers, multipliers 20, 21, 22 and 23, selector circuits 24, 25, 26, 27, 28, 29, 32, 33 and 36 and adders 38 and 41 of color separation circuit 8 is used.

More specifically, for the arrangement 1, selectors 27 and 36 are switched to their a terminals, respectively, and selectors 25, 28, 32 and 33 are switched to their b terminals, respectively. Therefore, the signal value S32 is multiplied by 2 in multiplier 21, and input through selectors 28 and 36 to adder 41. The signal value S12 is input through selectors 27 and 33 to adder 38. The signal value S34 is input through selectors 25 and 32 to adder 38. Therefore, from adder 38, a signal (S12+S34) is output. Finally, from adder 41, a signal (2×S32+S12+S34) would be output, which is the R signal at the interpolation portion Y.

For the arrangement 2, selectors 25, 28, and 36 are switched to their a terminals, respectively, and selectors 27, 32 and 33 are switched to their b terminals, respectively. Consequently, the signal value S33 is multiplied by 2 in multiplier 20, and input to adder 41 through selectors 28 and 36. The signal value S13 is input through selectors 27 and 33 to adder 38. Signal value S31 is input to adder 38 through selectors 25 and 32. Therefore, a signal (S13+S31) is output from adder 38. Finally, a signal (2×S33+S13+S31) would be output from adder 41, which is the R signal at interpolation portion Y.

For the arrangement 3, selectors 24, 32 and 33 are switched to their a terminals, respectively, and selectors 26, 29 and 36 are switched to their b terminals, respectively. Consequently, the signal value S22 is multiplied by 2 in multiplier 23 and input through selectors 29 and 36 to adder 41. The signal value S24 is input through selectors 26 and 33

to adder 38. The signal value S42 is input through selectors 24 and 32 to adder 38. Therefore, a signal (S24+S42) is output from adder 38. Finally, a signal (2×S22+S24+S42) would be output from adder 41, which is the R signal at the interpolation portion Y.

For the arrangement 4, selectors 26, 29, 32, and 33 are switched to their a terminals, respectively, and selectors 24 and 36 are switched to their b terminals, respectively. Consequently, the signal value S23 is multiplied by 2 in multiplier 22, and input through selectors 29 and 36 to adder 41. The signal value S21 is input to adder 38 through selectors 26 and 33. The signal value S43 is input through selectors 24 and 32 to adder 38. Therefore, a signal (S21+S43) is output from adder 38. Finally, a signal (2×S23+S21+S43) would be output from adder 41, which will be the R signal at interpolation portion Y.

The procedure for generating the B signal will be described in the following.

For generating the B signal at interpolation portion Y, one of the four pixels surrounding the interpolation portion Y and two pixels out of outermost 12 pixels belonging to the same row or same column as the one pixel, are used, that is, B signals from the total of these three pixels are used. More specifically, for the arrangement 1, weight coefficient of "2" is allotted to the B signal from pixel P23 and weight coefficient of "1" is allotted to the B signals from pixels P21 and P43 as shown in FIG. 10D. The B signals from these three pixels are multiplied by respective weight coefficients and the multiplied values are added, whereby the B signal of the interpolating portion Y is calculated.

Similarly, for the arrangement 2, weight coefficient of "2" is allotted to the B signal from pixel P22 and weight coefficient of "1" is allotted to the B signals from pixels P24 and P42, as shown in FIG. 11D. The B signals from these three pixels are multiplied by respective weight coefficients and the multiplied values are added, whereby the B signal at the interpolation portion Y is calculated.

For the arrangement 3, weight coefficient of "2" is allotted to the B signal from pixel P33 and weight coefficient of "1" is allotted to the B signals from pixels P13 and P31 as shown in FIG. 12D. The B signals from these three pixels are multiplied by respective weight coefficients, and the multiplied values are added, whereby the B signal at the interpolating portion Y is calculated.

For the arrangement 4, weight coefficient of "2" is allotted to the B signal from pixel P32 and weight coefficient of "1" is allotted to B signals from pixels P12 and P34, as shown in FIG. 13D. The B signals from these three pixels are multiplied by respective weight coefficients, and by adding these multiplied values, the B signal of the interpolating portion Y is calculated.

In this manner, when the B signal is to be calculated by weighting and adding, a two-dimensional three-tap filter including all the 1 clock delay providers, multipliers 20, 21, 22 and 23, selector circuits 24, 25, 26, 27, 28, 29, 34, 35, 37 and adders 39 and 42 of color separation circuit 8 is used.

More specifically, for the arrangement 1, selector circuits 26, 29, 34 and 35 are switched to their a terminals, respectively, and selector circuits 24 and 37 are switched to their b terminals, respectively. Therefore, the signal value S23 is multiplied by 2 in multiplier 22, and input through selectors 29 and 37 to adder 42. The signal value S21 is input through selectors 26 and 35 to adder 39. The signal value S43 is input through selectors 24 and 34 to adder 39. Therefore, a signal (S21+S43) is output from adder 39. Finally, a signal (2×S23+S21+S43) would be output from adder 42, which will be the B signal at interpolation portion Y.

For arrangement 2, selectors 24, 34, and 35 are switched to their a terminals, respectively, and selector circuits 26, 29 and 37 are switched to their b terminals, respectively. Consequently, the signal value S22 is multiplied by 2 in multiplier 23 and input to adder 42 through selector circuits 29 and 37. The signal value S24 is input through selector circuits 26 and 35 to adder 39. The signal value S42 is input through selector circuits 24 and 34 to adder 39. Therefore, a signal (S24+S42) is output from adder 39. Finally, a signal (2×S22+S24+S42) would be output from adder 42 which is the B signal at interpolation portion Y.

For the arrangement 3, selector circuits 25, 28 and 37 are switched to their a terminals, respectively, and selecting circuits 27, 34 and 35 are switched to their b terminals, respectively. Therefore, the signal value S33 is multiplied by 2 in multiplier 20 and input to adder 42 through selectors 28 and 37. The signal value S13 is input through selector circuits 27 and 35 to adder 39. The signal value S31 is input through selector circuits 25 and 34 to adder 39. Therefore, a signal (S13+S31) is output from adder 39. Finally, a signal (2×S33+S13+S31) would be output from adder 42, which is the B signal at interpolation portion Y.

For the arrangement 4, selector circuits 27 and 37 are switched to their a terminals, respectively, and selector circuits 25, 28, 34 and 35 are switched to their b terminals, respectively. Consequently, the signal value S32 is multiplied by 2 in multiplier 21, and input to adder 42 through selector circuits 28 and 37. The signal value S34 is input through selector circuits 25 and 34 to adder 39. Therefore, a signal (S12+S34) is output from adder 39. Finally, from adder 42, a signal (2×S32+S12+S34) would be output, which is the B signal at interpolating portion Y.

In the interpolation of R, G and B signals described above, it is also possible to utilize a weighted mean in which color signal values for each arrangement are divided by 4, i.e., the sum of weight coefficients.

In this manner, regardless of which of the four different arrangements corresponds to the arrangement of an arbitrary 4×4 pixel block on CCD 1, three primary signals of R, G and B can be calculated at interpolation portion Y of the pixel block in color separation circuit 8.

When generation of color signals at interpolation portion Y of a certain 4×4 pixel block is completed and image signal from the next pixel is output from A/D converter 4, the object pixel block is shifted by one pixel in horizontal direction, and similar processing is repeated. When this horizontal movement results in complete movement of one row in CCD 1, the pixel block of which interpolation is to be performed returns to the initial position horizontally while it is shifted by one pixel in vertical direction.

As the pixel block is shifted, the interpolation portion Y is also shifted in horizontal and vertical directions successively. Finally, as shown in FIG. 14, R, G and B signals at an intersection of four pixels on the CCD 1 are calculated. Here, the interpolation portion marked by the hatching in FIG. 14 indicates a central point of any pixel block if a 4×4 pixel block can be actually formed on the CCD 1.

Other than the hatched portion, it is possible to calculate values corresponding to R, G and B signals, based on the signals output from CCD 1 successively from color separation circuit 8. However, a 4×4 pixel block cannot be physically set on the CCD 1, and hence the calculated value is meaningless as data for interpolation.

Generally, on CCD 1, non-effective pixels which are not displayed on a monitor are arranged on left, right, upper and lower edges. Therefore, if the interpolation portions denoted

by the hatched portions in FIG. 14 are used as effective pixels and portions not hatched are set as non-effective pixels, only the color signals obtained from the effective pixels would be visible signals.

In FIG. 14, the pixels of CCD 1 have been described as having a scale of 8×8 for convenience of description. Therefore, hatched portions are smaller as compared with portions not hatched. However, generally, the total number of pixels of a CCD 1 is as large as about 530×500, and most of the total number of pixels can be occupied by the hatched portions, that is, portions where 4×4 pixel blocks can be set. In other words, most pixels can be used as effective pixels.

The transfer function of a two-dimension non-recursive digital filter for performing interpolation of color signals in color separation circuit 8 in the above described manner are as follows.

[ARRANGEMENT 1]

(HORIZONTAL & VERTICAL DIRECTIONS OF G SIGNAL)

$H(z) = \Sigma h m z^{-m} = 1 \times z^{-0} + 1 \times z = ^{-1} = 1 + z^{-1}$

(HORIZONTAL DIRECTION OF R SIGNAL) $H(z) = \Sigma h m z^{-m} = 0 \times z^{-0} + 3 \times z^{-1} + 0 \times 0^{-2} + 1 \times 2^{-3} = 3z^{-1} + z^{-3}$

(VERTICAL DIRECTION OF R SIGNAL)

$H(z) = \Sigma h m z^{-m} = 1 \times z^{-0} + 0 \times z^{-1} 3 \times z^{-2} + 0 \times z^{-3} = 1 + 3z^{-2}$

(HORIZONTAL DIRECTION OF B SIGNAL $H(z) = \Sigma h m z^{-m} = 1 \times z^{-0} + 0 \times z^{-1} + 3 \times z^{-2} 0 \times z^{-3} = 1 + 3z^{-2}$

(VERTICAL DIRECTION OF B SIGNAL) $H(z) = \Sigma h m z^{-m} = 0 \times z^{-0} + 3 \times z^{-1} + 0 \times z^{-2} + 1 \times z^{-3} = 3z^{-1} + z^{-3}$

[ARRANGEMENT 2]

(HORIZONTAL & VERTICAL DIRECTIONS OF G SIGNAL)

$H(z) = \Sigma h m z^{-m} = 1 \times z^{-0} + 1 \times z^{-1} = 1 + z^{-1}$

(HORIZONTAL DIRECTION OF R SIGNAL)

$H(z) = \Sigma h m z^{-m} = 1 \times z^{-0} + 0 \times z^{-1} = 3 \times z^{-2} + 0 \times z^{-3} = 1 + 3z^{-2}$

(VERTICAL DIRECTION OF R SIGNAL)

$H(z) = \Sigma h m z^{-m} = 1 \times z^{-0} + 0 \times z^{-1} + 3 \times z^{-2} + 0 \times z^{-3} = 1 + 3z^{-2}$

(HORIZONTAL DIRECTION OF B SIGNAL)

$H(z) = \Sigma h m z^{-m} = 0 \times z^{-0} + 3 \times z^{-1} + 0 \times z^{-2} + 1 \times z^{-3} 3z^{-1} + z^{-3}$

(VERTICAL DIRECTION OF B SIGNAL) $H(z) = \Sigma h m z^{-m} = 0 \times z^{-0} 3 \times z^{-1} + 0 \times z^{-2} + 1 \times z^{-3} = 3z^{-1} + z^{-3}$

[ARRANGEMENT 3]

(HORIZONTAL & VERTICAL DIRECTIONS OF G SIGNAL)

$H(z) = \Sigma h m z^{-m} = 1 \times z^{-0} + 1 \times z^{-1} = 1 + z^{-1}$

$H(z) = \Sigma h m z^{-m} = 0 \times z^{-0} + 3 \times z^{-1} + 0 \times z^{-2} + 1 \times z^{-3} = 3z^{-1} + z^{-3}$

(VERTICAL DIRECTION OF R SIGNAL)

$H(z) = \Sigma h m z^{-m} = 0 \times z^{-0} + 3 \times z^{-1} + 0 \times z^{-2} + 1 \times z^{-3} = 3z^{-1} + z^{-3}$

(HORIZONTAL DIRECTION OF B SIGNAL)

$H(z) = \Sigma h m s^{-m} = 1 \times z^{-0} + 0 \times z^{-1} + 3 \times z^{-2} + 0 \times z^{-3} = 1 + 3z^{-2}$

(VERTICAL DIRECTION OF B SIGNAL) $H(z) \Sigma h m s^{-m} = 1 \times z^{-0} + 0 \times z^{-1} + 3 \times z^{-2} + 0 \times z^{-3} = 1 + 3z^{-2}$

[ARRANGEMENT 4]

(HORIZONTAL & VERTICAL SIGNALS OF G SIGNAL)

$H(z) = \Sigma h m z^{-m} = 1 \times z^{-0} + 1 \times z^{-1} = 1 + z^{-1}$

(HORIZONTAL DIRECTION OF R SIGNAL) $H(z) = \Sigma h m z^{-m} = 1 \times z^{-0} + 0 \times z^{-1} + 3 \times z^{-2} + 0 \times z^{-3} = 1 + 3z^{-2}$

(VERTICAL DIRECTION OF R SIGNAL) $H(z) = \Sigma h m z^{-m} = 0 \times z^{-0} + 3 \times z^{-1} + 0 \times z^{-2} + 1 \times z^{-3} = 3z^{-1} + z^{-3}$

(HORIZONTAL DIRECTION OF B SIGNAL)

$H(z) = \Sigma h m z^{-m} = 0 \times z^{-0} + 3 \times z^{-1} + 0 \times z^{-2} + 1 \times z^{-3} = 3z^{-1} + z^{-3}$

(VERTICAL DIRECTION OF B SIGNAL)

$H(z) = \Sigma h m z - m = 1 \times z^{-0} + 0 \times z^{-1} + 3 \times z^{-2} + 0 \times z^{-3} = 1 + 3z^{-2}$

The frequency characteristics of color signals which are the output signals of the two-dimensional non-recursive digital filter having such transfer functions are as shown in FIG. 15. In the graph, the curve Q1 shows horizontal and vertical characteristics of G signal, and curve Q2 shows horizontal and vertical characteristics of R and B signals.

As is apparent from FIGS. 10B to 14B, the pixels used for generating the G signal exist at the central two columns out of four columns when viewed horizontally, and exist in the central two columns when viewed vertically. Therefore, in any of the arrangements 1 to 4, the gain lowers near the Nyquist frequency.

The sum of the weight coefficients of the pixels used for generating the R signal, when viewed horizontal, any of the central two columns out of four columns is "3", and in the column outer by one column, it would be "1". Meanwhile, when viewed vertically, either of the central two rows out of four rows is always "3", and an outer row spaced by one row is "1". Therefore, frequency characteristic of R signal is always as represented by Q2.

Similarly to R signals, the sum of the weight coefficients of the pixels used for generating the B signal is, when viewed horizontally, either of the central two of four columns is always "3" and an outer column spaced by one column is "1". When viewed vertically, it is always "3" in either of the central two rows out of four rows, and in the outer row spaced by one row, it is "1". Therefore, the frequency characteristic of the B signal is always as represented by Q2.

As is apparent from FIG. 15, the frequency characteristic Q1 of the G signal, which has highest contribution to brightness among then three primary signals, exhibits relatively little attenuation in the higher frequency range as compared with the curve P2 shown in FIG. 7, which means that higher resolution is possible.

Further, at ½ Nyquist frequency, the difference between frequency characteristic of R and B signals over the frequency characteristic of G signal is considerably smaller than in FIG. 7, and hence generation of a false color signal can be suppressed.

Therefore, according to the present invention, a frequency characteristic which exhibit relatively little attenuation in high frequency range can be provided for the G signal which has highest contribution to brightness, so that high resolution can be obtained. Further, at ½ Nyquist frequency, the difference between frequency characteristic of R and B signals and G signal is small, and hence generation of a false color signal can be suppressed. Further, the same frequency characteristic can be obtained for every pixel, for each of the three primary colors.

Although the present invention has been described and illustrated in detail, it is clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of the present invention being limited only by the terms of the appended claims.

What is claimed is:

1. A 1-chip color video camera, comprising:

solid-state image sensing means provided with photoelectric converting elements corresponding to respective pixels arranged in an array;

said solid-state image sensing means including on its light receiving surface a color filter array in which primary color filters are placed in a prescribed arrangement corresponding to said photoelectric converting elements; and

interpolating means, receiving an output from said solid-state image sensing means, for outputting color signals;

said interpolating means including:

parallel color signal output means, receiving said output from said solid-state image sensing means, for outputting, as said color signals, color signals corresponding to a prescribed even number of rows of said pixels in synchronization with and parallel to each other successively, column by column;

control means for outputting a synchronized interpolation designating signal in accordance with correspondence between said color signals, output column by column from said parallel color signal output means, and an arrangement of predetermined weight coefficients for the prescribed arrangement of said color filter array; and

color separation means, receiving said outputs from said parallel color signal output means, for interpolating color signals from a pixel block including pixels of said prescribed even number of rows and a prescribed even number of columns in accordance with said interpolation designating signal, and for successively outputting color signals in synchronization with and corresponding to a central position of said pixel block.

2. A 1-chip color video camera, comprising:

solid-state image sensing means provided with photoelectric converting elements corresponding to respective pixels arranged in an array;

said solid-state image sensing means including on its light receiving surface a color filter array in which primary color filters are arranged mosaic-wise corresponding to said photoelectric converting elements;

said color filter array having green filters placed in a diagonal direction in an arbitrary color filter arrangement of two rows by two columns; and

interpolating means, receiving an output from said solid-state image sensing means, for interpolating a green signal component at a central portion of a pixel block corresponding to said arbitrary color filter arrangement of two rows by two columns, using a mean value of a plurality of green signals from those of said photoelectric converting elements which correspond to said green filters placed in the diagonal direction.

3. A 1-chip color video camera, comprising:

solid-state image sensing means provided with photoelectric converting elements corresponding to respective pixels arranged in an array;

said solid-state image sensing means including, on its light receiving surface, a color filter array in which primary color filters are arranged mosaic-wise corresponding to said photoelectric converting elements; and

said color filter array having red filters and blue filters arranged checkerwise, with rows including said red filters and rows including said blue filters being arranged alternately; and

interpolating means for interpolating, based on signals from a pixel block including sixteen pixels of four rows by four columns, a color signal component of each of red and blue at a central portion of said pixel block;

said interpolating means including a two-dimensional non-recursive digital filter circuit for switching, in accordance with an arrangement of the color filters corresponding to said sixteen pixels, values of sums of weight coefficients of every column in a vertical direction to [0, 3, 0, 1] or [1, 0, 3, 0].

4. A 1-chip color video camera comprising:

solid-state image sensing means provided with photoelectric converting elements corresponding to respective pixels arranged in an array;

said solid-state image sensing means including, on its light receiving surface, a color filter array in which primary color filters are arranged mosaic-wise corresponding to said photoelectric converting elements; and

said color filter array having red filters and blue filters arranged checkerwise, with rows including said red filters and rows including said blue filters being arranged alternately; and

interpolating means for interpolating, based on signals from a pixel block including sixteen pixels of four rows by four columns, a color signal component of each of red and blue at a central portion of said pixel block;

said interpolating means including a two-dimensional non-recursive digital filter for switching, in accordance with an arrangement of the color filters corresponding to said sixteen pixels, values of sums of weight coefficients of every row in a horizontal direction to [0, 3, 0, 1] or [1, 0, 3, 0].

5. A 1-chip color video camera, comprising:

solid-state image sensing means provided with photoelectric converting elements corresponding to respective pixels arranged in an array;

said solid-state image sensing means including, on its light receiving surface, a color filter array in which primary color filters are arranged mosaic-wise corresponding to said photoelectric converting elements; and

said color filter array having red filters and blue filters arranged checkerwise, with rows including said red filters and rows including said blue filters being arranged alternately; and

interpolating means for interpolating, based on signals from a pixel block including sixteen pixels of four rows by four columns, a color signal component of each of red and blue at a central portion of said pixel block; and

said interpolating means including a two-dimensional non-recursive digital filter circuit;

wherein when said pixel block of sixteen pixels includes sixteen pixels of four rows by four columns from (m, n) to (m+3, n+3) with m and n being integers; and

said two-dimensional non-recursive digital filter circuit performs interpolation by:

setting a weight coefficient of a pixel (m+1, n+1) to 2 and a weight coefficient of each of pixels (m+1, n30 3) and (m+3, n+1) to 1, when either a red or a blue color filter is placed on the pixel (m+1, n+1);

setting a weight coefficient of a pixel (m+1, n+2) to 2 and a weight coefficient of each of pixels (m+1, n) and (m+3, n+2) to 1, when either a red or a blue color filter is placed on the pixel (m+1, n+2);

setting a weight coefficient of a pixel (m+2, n+1) to 2 and a weight coefficient of each of pixels (m, n+1) and (m+2, n30 3) to 1, when either a red or a blue color filter is placed on the pixel (m+2, n+1); and

setting a weight coefficient of a pixel (m+2, n+2) to 2 and a weight coefficient of each of pixels (m, n+2) and (m+2, n) to 1, when either a red or a blue color filter is placed on the pixel (m+2, n+2).

6. The 1-chip color video camera according to claim 1, further comprising:

analog-to-digital converting means, receiving said output from said solid-state image sensing means, for outputting a corresponding digital signal thereto;

wherein

said parallel color signal output means includes (2k-1) line memories, where 2k represents said prescribed even number;

each of said line memories having transfer capacity corresponding to a row of said pixels, and said line memories being connected in series to receive as an initial stage input, an output from said analog-to-digital converting means; and

said parallel color signal output means outputs, in parallel, said output from said analog-to-digital converting means and outputs from said line memories; and

said color separation means includes:

a two-dimensional transfer register, receiving said parallel color signal outputs, for successively transferring said parallel color signal outputs to a prescribed direction, and holding at most 2k×2k color signal values; and

interpolation calculation means, responsive to said interpolation designating signal, for adding corresponding ones of said color signals held in said two-dimensional transfer register to each other, in accordance with an arrangement of said weight coefficients.

7. The 1-chip color video camera according to claim 6, wherein:

said color filter array includes green filters arranged in a diagonal direction in an arbitrary color filter arrangement of two rows by two columns; and

said interpolation calculation means outputs, in accordance with said interpolation designating signal, a green signal corresponding to a central position of said pixel block as either a mean value of color signal values of (k, k) and (k+1, k+1) or a mean value of color signal values of (k+1, k) and (k, k+1), of the two-dimensional arrangement of said 2k×2k color signal values.

8. The 1-chip color video camera according to claim 6, wherein:

said prescribed even number is 4;

said color filter array includes red filters and blue filters arranged checkerwise, with rows including said red filters and rows including said blue filters being arranged alternately;

said two-dimensional transfer register holds signals from a pixel block including sixteen pixels of four rows by four columns; and

said interpolation calculation means switches, in accordance with said interpolation designating signal, values of sums of weight coefficients in every column in a vertical direction for color signals corresponding to said sixteen pixels to [0, 3, 0, 1] or [1, 0, 3, 0], for interpolating and outputting color signal component of each of red and blue at a central portion of said pixel block.

9. The 1-chip color video camera according to claim 6, wherein:

said prescribed even number is 4;

said color filter array includes red filters and blue filters arranged checkerwise, with rows including said red filters and rows including said blue filters being arranged alternately;

said two-dimensional transfer register holds signals from a pixel block including sixteen pixels of four rows by four columns; and

said interpolation calculation means for switching, in accordance with said interpolation designating signal, values of sums of weight coefficients of every row in horizontal direction for color signals corresponding to said sixteen pixels to [0, 3, 0, 1] or [1, 0, 3, 0], and for interpolating and outputting a color signal component of each of red and blue at a central portion of said pixel block.

10. The 1-chip color video camera according to claim 6, wherein:

said prescribed even number is 4;

said color filter array includes red filters and blue filters arranged checkerwise, with rows including said red filters and rows including said blue filters being arranged alternately;

said two-dimensional transfer register holds signals from a pixel block including sixteen pixels of four rows by four columns; and

said interpolation calculation means performs interpolation in accordance with said interpolation designating signal, where said pixel block of 16 pixels includes sixteen pixels of four rows by four columns of (m, n) to (m+3, n30 3), by:

setting a weight coefficient of a pixel (m+1, n+1) to 2 and a weight coefficient of each of pixels (m+1, n30 3) and (m+3, n+1) to 1, when either a red or a blue color filter is placed on the pixel (m+1, n+1);

setting a weight coefficient of a pixel (m+1, n+2) to 2 and a weight coefficient of each of pixels (m+1, n) and (m+3, n+2) to 1, when either a red or a blue color filter is placed on the pixel (m+1, n+2);

setting a weight coefficient of a pixel (m+2, n+1) to 2 and a weight coefficient of each of pixels (m, n+1) and (n+2, n30 3) to 1, when either a red or a blue color filter is placed on the pixel (m+2, n+1); and

setting a weight coefficient of a pixel (m+2, n+2) to 2 and a weight coefficient of each of pixels (m, n+2) and (m+2, n) to 1, when either a red or a blue color filter is placed on the pixel (m+2, n+2).

11. A 1-chip color video camera, comprising:

solid-state image sensing means provided with photoelectric converting elements corresponding to respective pixels arranged in an array;

said solid-state image sensing means, including on its light receiving surface a color filter array in which primary color filters are arranged mosaic-wise corresponding to said photoelectric converting elements; and

interpolating means for generating each of a plurality of primary color signal components at a position shifted by half a pixel in horizontal and vertical directions from a center of an arbitrary pixel, from color signal components of a plurality of neighboring pixels, based on a predetermined weighted average of corresponding primary color signal components from a plurality of neighboring pixels to the center pixel and according to a prescribed arrangement of said color filter array.

12. A 1-chip color video camera, comprising:

solid-state image sensing means having color filters of three primary colors of R, G and B (red, green and blue, respectively) arranged mosaic-wise corresponding to respective pixels;

color separation means for processing a signal from said solid-state image sensing means;

said color separation means including signal processing means for performing weighted average processing to obtain a weighted average of R, G and B color signal components at a central position of a pixel block consisting of 16 pixels of 4 rows by 4 columns of (m, n) to (m+3, n30 3), where m and n are integers, using a prescribed weight coefficient for a signal from a prescribed pixel in said pixel block, wherein:

if a first value is larger than a second value, said weighted average processing is performed when:

i) the R or B color filter is arranged on a pixel at (m+1, n+1), and using a weight coefficient for the pixel (m+1, n+1) as the first value and a weight coefficient of pixels at (m+1, n30 3) and (m+3, n+1) as the second value;

ii) the R or B color filter is arranged on a pixel at (m+1, n+2), and using a weight coefficient for the pixel (m+1, n+2) as the first value and a weight coefficient of pixels at (m+1, n) and (m+3, n+2) as the second value;

iii) the R or B color filter is arranged on a pixel at (m+2, n+1), and using a weight coefficient for the pixel (m+2, n+1) as the first value and a weight coefficient of pixels at (m, n+1) and (m+2, n30 3) as the second value; and

iv) the R or B color filter is arranged on a pixel at (m+2, n+2), and using a weight coefficient for the pixel (m+2, n+2) as the first value and a weight coefficient of pixels at (m, n+2) and (m+2, n) as the second value.

13. A 1-chip video camera, comprising:

solid-state image sensing means having color filters of three primary colors R, G and B (red, green and blue, respectively) arranged mosaic-wise corresponding to respective pixels; and

interpolating means for generating R, G and B color signal data at a central position of a pixel block, the block consisting of an arbitrary v rows by v columns, where v is an even number, and using a prescribed weight coefficient for a signal for each color for a prescribed pixel in said pixel block.

14. A 1-chip color video camera according to claim 13, wherein said color filters comprises:

B color filters and G color filters arranged alternately for each of the pixels in one row of every two rows adjacent to each other in a vertical direction; and

G filters and R filters arranged alternately offset by one pixel in the vertical direction from said one row, and on each one of the pixels of the other one of said two rows.

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